A COMPARATIVE EVALUATION OF RETRIEVABILITY OF GUTTA PERCHA, RESILON AND CPOINTS FOR RETREATMENT USING TWO DIFFERENT ROTARY RETRIEVAL SYSTEMS - AN *INVITRO* STUDY

Dissertation submitted to

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In Partial fulfillment of the degree of

MASTER OF DENTAL SURGERY

BRANCH IV

CONSERVATIVE DENTISTRY

AND ENDODONTICS

2014-2017

CERTIFICATE

This is to certify that this dissertation titled **"A comparative evaluation of retrievability of Gutta percha, Resilon and CPoints for retreatment using two different rotary retrieval systems - an *invitro* study"** *is a bonafide record of the work done by* ***Dr. Aswathy Prasad****, under our guidance during her post graduate study during the period of 2014-2017 under* **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY, CHENNAI**, *in partial fulfillment for the degree of* **MASTER OF DENTAL SURGERY IN CONSERVATIVE DENTISTRY & ENDODONTICS, BRANCH IV**. *It has not been submitted (partial or full) for the award of any other degree or diploma.*

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DECLARATION

I hereby declare that this dissertation "**A COMPARATIVE EVALUATION OF RETRIEVABILITY OF GUTTA PERCHA, RESILON AND CPOINTS FOR RETREATMENT USING TWO DIFFERENT ROTARY RETRIEVAL SYSTEMS - AN *INVITRO* STUDY**" is a bonafide record of work undertaken by me during the period 2014-2017 as a part of post graduate study. This dissertation, either in partial or in full, has not been submitted earlier for the award of any degree, diploma, fellowship or similar title of recognition.

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[This Institutional Human Ethics Committee is organized and is operating according to the requirements of ICH-GCP/GLP guidelines and requirements of the Amended Schedule-Y of Drugs and Cosmetics Act, 1940 and Rules 1945 of Government of India.]

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CONTENTS

Sl.No.	INDEX	PAGE NO
1.	List of Abbreviations	i
2.	List of Tables	ii - iii
3.	List of Figures	iv - vii
4.	Abstract	viii- x
5.	Introduction	1 – 6
6.	Aims & Objectives	7
7.	Review of Literature	8 – 28
8.	Materials & Methods	29 - 36
9.	Results & Observations	37- 44
10.	Discussion	45 - 65
11.	Summary & Conclusion	66 – 68
12.	Tables	xi - xviii
13.	Figures	xix- xxxix
14.	Bibliography	xl – lv

LIST OF ABBREVIATIONS

ANOVA – Analysis of Variance	K file -Kerr file
BC – Bioceramic	Mm – millimeter
CBCT – Cone Beam Computed Tomography	NiTi – Nickel Titanium
EDTA – Ethylene diamine tetra acetic acid	NaOCl – Sodium hypochlorite
Eg – example	Protaper UR – Protaper Universal Rotary files
Etc – etcetera	Protaper R – Protaper Universal retreatment files
Fig – figure	SE – Self Etch
GP – gutta percha	SEM – Scanning Electron Microscope
HEMA – Hydroxyethyl methacrylate	SPSS – Statistical Package for Social Sciences
H file – Hedstrom files	UDMA – Urethane Dimethacrylate
i.e – that is	

LIST OF TABLES

Table 1	Mean volume before retreatment, after removal and percentage of total of different groups
Table 2	Comparison of mean values before retreatment and after removal within the groups
Table 3	Comparison of mean values between Group-I and Group-II
Table 4	Comparison of mean values between Group-III and Group-IV
Table 5	Comparison of mean values between Group-V and Group-VI
Table 6	Comparison of mean values Group-I with other groups
Table 7	Comparison of mean values Group-II with other groups
Table 8	Comparison of mean values Group-III with other groups

Table 9	Comparison of mean values Group-IV with other groups
Table 10	Comparison of mean values Group-V with other groups
Table 11	Comparison of mean values Group-VI with other groups
Table 12	Multiple comparisons of mean values between the groups
Table 13	Multiple comparisons of mean total percentage values between the groups

LIST OF FIGURES

Fig 1	Armamentarium
Fig 2	Sixty extracted single rooted mandibular premolar teeth
Fig 3	Decoronation
Fig 4	Working length determination
Fig 5	CBCT – CS9300 equipment (Carestream Healthcare India Pvt. Ltd.)
Fig 6 a	Tooth preparation with Sx Protaper file
Fig 6 b	Tooth preparation with S1 Protaper file
Fig 6 c	Tooth preparation with S2 Protaper file
Fig 6 d	Tooth preparation with F1 Protaper file
Fig 6 e	Tooth preparation with F2 Protaper file
Fig 7 a	AH Plus Sealer dispensed on mixing pad
Fig 7 b	Sealer mixing
Fig 7 c	Guttapercha Mastercone placement coated with sealer
Fig 7 d	Lateral condensation
Fig 7 e	Completed obturation
Fig 8 a	Dispensed sealer – RealSeal SE
Fig 8 b	Resilon Master cone placement coated with sealer
Fig 8 c	Lateral condensation
Fig 8 d	Light curing of the sealer

Fig 8 e	Completed obturation
Fig 9 a	Dispensed sealer
Fig 9 b	F2 size - verifier and Cpoint
Fig 9 c	Application of Endosequence BC sealer
Fig 9 d	Check for fit with verifier
Fig 9 e	Single cone obturation with CPoint and Endosequence
Fig 10	CBCT image of group I before retreatment
Fig 11	CBCT image of group II before retreatment
Fig 12	CBCT image of group III before retreatment
Fig 13	CBCT image of group IV before retreatment
Fig 14	CBCT image of group V before retreatment
Fig 15	CBCT image of group VI before retreatment
Fig 16	Protaper retreatment files – D1, D2, D3
Fig 17 a, b, c	Retreatment of group I with Protaper retreatment files
Fig 18 a, b, c	Retreatment of group III with Protaper retreatment files
Fig 19 a, b, c	Retreatment of group IV Protaper retreatment files
Fig 20	Mtwo retreatment files – R1 and R2
Fig 21 a, b	Retreatment of group II with Mtwo retreatment files
Fig 22 a, b	Retreatment of group IV with Mtwo retreatment files
Fig 23 a, b	Retreatment of group VI with Mtwo retreatment files
Fig 24	CBCT images of group I after removal

Fig 25	CBCT images of group II after removal
Fig 26	CBCT images of group III after removal
Fig 27	CBCT images of group IV after removal
Fig 28	CBCT images of group V after removal
Fig 29	CBCT images of group VI after removal
Fig 30	Graphical representation of Mean before retreatment, after removal and percentage of total of different groups
Fig 31	Graphical representation of Comparison of mean values before retreatment and after removal within the groups
Fig 32	Graphical representation of Comparison of mean values between Group-I and Group-II
Fig 33	Graphical representation of Comparison of mean values between Group-III and Group-IV
Fig 34	Graphical representation of Comparison of mean values between Group-V and Group-VI
Fig 35	Graphical representation of Comparison of mean values Group-I with other groups
Fig 36	Graphical representation of Comparison of mean values Group-II with other groups
Fig 37	Graphical representation of Comparison of mean values Group-III with other groups

Fig 38	Graphical representation of Comparison of mean values Group-IV with other groups
Fig 39	Graphical representation of Comparison of mean values Group-V with other groups
Fig 40	Graphical representation of Comparison of mean values Group-VI with other groups
Fig 41	Graphical representation of Multiple comparisons of mean values between the groups
Fig 42	Graphical representation of Multiple comparisons of mean total percentage values between the groups

ABSTRACT

Introduction

The success of endodontic treatment depends on thorough debridement of canal system, of infected or necrotic pulp tissue, microorganisms and complete sealing of the canal space, thus preventing persistence of infection and/or reinfection of the pulp cavity. A number of endodontic failure cases are being reported to the dental clinics which require surgical or nonsurgical retreatment. Nonsurgical retreatment requires regaining access to the entire root canal system through complete removal of the core filling material and sealer. For retreatment to be practical, the material should be removable from the root canal space.

Aims and objectives

To compare the removal ability of Gutta percha, Resilon and CPoints, for retreatment, using two rotary retreatment systems, Protaper and Mtwo and comparing volume percentage of residual obturating material in the root canal walls, after removal, using the Cone Beam Computed Tomography images.

Methodology

Sixty freshly extracted single rooted mandibular premolars which were extracted for orthodontic purpose, were collected and were decoronated at the cemento-enamel junction, approximately 15mm from apex. They were randomly divided into six groups of ten teeth each. Biomechanical preparation

using Protaper rotary files and obturation of root canals using Gutta percha, Resilon and CPoints, using their corresponding sealers, were performed for twenty teeth each. The obturation material was removed with Protaper rotary retreatment files for 10 teeth each from each group obturated with gutta-percha, Resilon and CPoint. The rest were removed using Mtwo rotary retreatment files. All teeth, after removal of obturation material was analysed using Cone Beam Computed Tomography, for checking the cleanliness of root canals and the remaining percentage volume of obturation material from each group was calculated and compared.

Results and observations

The analysis of the results show that the mean volume percentage of the residual material is least for RealSeal group with the removal by Protaper retreatment file(16.35±2.69 %) and the highest volume percentage of residual filling material was seen in the groups obturated by CPoint and removed by Mtwo retreatment file system (29.67±2.34 %).

Conclusion

In this study, it is well demonstrated that the canals obturated with CPoints were least retreatable and those with RealSeal were the easiest ones to be retreated.

Clinical significance

Many retreatment cases are being reported to our clinics nowadays. Root canal treatment failures occur when the treatment falls short of the acceptable standards. It is usually associated with procedural errors in infected tooth. It may be due to intra-radicular or extra-radicular infections or due to overfilling of root canals or inadequate coronal seal. Retreatment has to be done in such cases and hence the obturating materials used must be retrievable from the root canals. It is a consensus that all filling material must be removed during retreatment thus providing adequate disinfection of the root canal system and favours conditions for new filling.

The three different materials in this study shows three different sealing efficiency which affects the retrievability of the material from root canal. Hence the retrievability of each obturating material from the canal walls was evaluated by measuring the percentage volume of residual root canal obturating material to the total volume of root canal after the obturating material is removed by two retreatment file systems.

Keywords: CPoint, Guttapercha**,** Resilon, Retreatment, Protaper retreatment file, Mtwo retreatment file, Cone Beam Computed Tomography

INTRODUCTION

The success of endodontic treatment depends on thorough debridement of root canal system, of infected or necrotic pulp tissue, microorganisms and complete sealing of the canal space, thus preventing persistence of infection and reinfection of the pulp cavity.[1] The clinical success rate of endodontic treatment ranges between 50-90 %.[2-3] This variability in the success rate of root canal treatment is determined by various factors like age of the patient, the tooth which is being treated, alterations in the natural anatomy of root canal by procedural errors, the ability in removal of coronal restoration for proper access to the pulp chamber and the ability to repair the pathologic and iatrogenic errors. Preoperative perforation, apical periodontitis and the quality of the filling material also determine the outcome of endodontic treatment.[4,5,6] Numerous factors contribute to endodontic treatment failure which includes positive culture, broken instruments, canal over fillings, mechanical perforations, root fractures, presence of periradicular lesions and periodontal disease. A number of studies have also reported that endodontic treatment failures are greater in teeth that are associated with pre-treatment periradicular radiolucencies than in teeth without them.[7]

Conventional endodontic retreatment is one of greatest technical difficulties faced by endodontists, as filling materials represent a mechanical barrier that can often demand considerable time and effort to be removed. It requires regaining access to the root canal system by removal of the original filling with endodontic hand files, heated instruments, ultrasonic instruments or

engine driven rotary files followed by cleaning, shaping and reobturation.[8] Post-treatment disease might persist or emerge because of persistent bacteria in the root canal system as a consequence of insufficient cleaning, untreated canals, inadequate filling or coronal leakage.[9] Cross-sectional studies have demonstrated persistent apical periodontitis associated with over 45% of endodontically treated teeth. Persistent apical periodontitis is caused mainly by root canal bacteria that survive primary treatment.[10] It can be treated by means of orthograde retreatment. The primary purpose of the retreatment therapy is adequate cleaning and disinfection of the root canal system. During retreatment, it is essential to remove all the filling material, that hinders contact of irrigating solutions and intra canal dressings with the root canal walls, so that the residual microbial population can be eliminated and create favourable conditions for periradicular healing.[11] To allow retreatment when indicated, the obturating material should be removable.[10,11]

Most widely accepted root canal filling material is gutta-percha (GP) in conjunction with a variety of sealers. However it has many drawbacks like poor sealing ability and its inability to further strengthen the teeth and thus reducing susceptibility to fracture. AH Plus is a thermoplastic, two-component paste root canal sealer based epoxy-amine resin, which permits removal of the material, if necessary, hence the most preferred.[9,10,11]

Resilon™ a thermoplastic, synthetic, polyester polymer-based root canal filling material containing bioactive glass and radiopaque fillers like bismuth oxychloride and bariumsulfate, was proposed as an alternative to Gutta percha,

and was introduced in 2004. Many studies have proved that the performance and handling properties of Resilon is similar to that of Gutta percha.[9,10,11,12] Resilon bonds to dentinal walls when used in conjunction with its root canal sealer, Epiphany/Real Seal SE and forms a 'monoblock' within the canal.[13, 14] This prevents the chances of microleakage between core material-sealer interface and the sealer-dentin interface.[15] The Resilon sealer is a dual-curable dental-resin composite sealer, which has a total filler content of about 70% of its weight, allowing its easy removal in retreatment cases. The fillers include calcium hydroxide, bariumsulfate, barium glass and silica. Resilon cones come in a range of sizes similar to gutta-percha cones. The Resilon bonding agent is a self-etching primer that contains sulfonic-acid terminated functional monomer, HEMA, water and a polymerization initiator.[16]

CPoint is a self-sealing obturating system. It is made from contact lens plastic, and has been shown to reduce intraoperative treatment complications by eliminating heating or compaction. Once placed in the canal with its companion bioceramic sealer, EndoSequence BC, the CPoint uses dentinal moisture to radially expand and seal the canal making it virtually impermeable to bacterial microleakage.[17] CPoints have a 2 component design, with a central core (a combination of two nylon polymers, Trogamid T and Trogamid CX) to provide good handling characteristics and a hydrophilic outer polymer coating of a cross-linked copolymer of acrylonitrile and vinylpyrrolidone, which has been cross-linked using allyl methacrylate and a thermal initiator. This hydrophilic, hydrogel layer allows the point to swell laterally rather than

axially to adapt to the ramifications of the root canal. When hydrated in the root canal, CPoints expand, conforming to canal irregularities and pressing the companion hydrophilic sealer, into concavities, lateral portals of exit and the tubules of the dentin walls.[18]

K files and H files took longer time and were ineffective in the complete removal of obturation materials in the root canal.[25,30,32] Ni-Ti files have the disadvantage of higher incidence of file fracture and apical extrusion of debris. Hence to overcome these drawbacks newer rotary retreatment systems like Protaper universal retreatment files were introduced.[19,20] They have been used increasingly in root canal preparation and to remove filling materials because of their unique physical properties, resilience, high safety and cutting efficiency, providing efficient removal of obturation materials, maintenance of canal shape and shorter working time with limited usage of solvents.[19,20]

Protaper universal files with its rounded tip and increased flexibility makes it a good rotary file system for biomechanical preparation of root canals. It has three files for coronal preparation (SX, S1, S2) and five finishing files (F1, F2, F3, F4, F5) for apical preparation.[11]

Protaper universal retreatment system has 3 files - D1, D2, and D3. The D1 is used for initial penetration. The D1 has an active cutting tip and has a length of 16mm and tip of 0.30mm with 0.09% taper. D2 and D3 have non-active tips that have been designed to closely respect the path of the canal and are used in the mid and apical thirds of the canal respectively. The D2 used in

middle third, has a length of 18mm and tip of 0.25mm with 0.08% taper. The D3 is used in apical third, has length of 22mm and tip of 0.20mm with 0.07% taper.[11]

The Mtwo instruments have an S-shaped cross-section, an increasing pitch length in the apical-coronal direction. The Mtwo retreatment kit consists of only two instruments with cutting tips, i.e., Mtwo R_1 15/.05 and Mtwo R_2 25/.05, designed to reach the apex. They too have an S-shaped cross-section as do the files of the basic sequence, but a shorter pitch length to enhance the advancement of the file into the filling material. These instruments are characterized by two cutting edges, which are claimed to cut dentine effectively. They also have the advantage of shaping the root canal in an under-prepared tooth, simultaneously.[9]

Amount of filling materials remaining inside the root canal after retreatment procedure can be assessed by various methods like radiographic interpretation, longitudinal splitting of the roots, and measuring of the remaining material by computed tomography or operating microscopes. Computed tomography helps in both qualitative and quantitative evaluation of the retreatment procedures. Cone Beam Computed Tomography (CBCT) has reduced acquisition time and has lower radiation dosage. Even though the field of view is limited, it has a very good spatial resolution in all planes. CBCT has the advantage of ability to study the images using different representation, multiplanar reformation and 3D surface rendering. They can be rotated in any plane without superimposition of the anatomical structures.[21]

In the present study, the removal ability of Gutta percha, Resilon and C-point using Protaper retreatment files and Mtwo retreatment files is evaluated, by analysing the amount of remaining obturation material in the root canal after removal, using CBCT.

The study hypothesis was that CPoint would be the most difficult to be removed due to its ability to expand, conforming to canal irregularities and pressing the companion hydrophilic bioceramic sealer, Endosequence BC, into concavities, lateral portals of exit and the tubules of the dentin walls forming a good seal with root canal and hence not easily retreatable.

AIMS AND OBJECTIVES

Aim

To compare the removal ability of Gutta percha, Resilon and CPoints, for retreatment, using two rotary retreatment systems – Protaper and Mtwo.

Objectives

1. To observe the removal ability of Gutta percha, Resilon and CPoints from root canals by two rotary retreatment file systems, after obturation.
2. To compare the volume percentage of residual obturating material in the root canal walls, after removal using Protaper retreatment files and Mtwo retreatment files, using Cone Beam Computed Tomography analysis.

REVIEW OF LITERATURE

Bergenholtz *et al.*1979[22] studied the effects of endodontic retreatment on quality of seal and periapical healing and concluded that nonsurgical retreatment should be attempted if necessary before proceeding for surgical intervention.

Wilcox LR *et al.*1987[1] compared the retrievability of gutta-percha along with different sealers and found out that none of the materials were completely removable from the canals.

Gilbert BO *et al.*1987[23] in their review article has emphasised the need to remove the previous obturation material as the initial step, which when successfully accomplished, provides access to the root canal system so that treatment objectives can be carried out successfully.

Hülsmann M *et al.*1997[24] evaluated the efficacy of different methods for gutta-percha removal and concluded that cleaner canals were achieved with the use of Hand files compared to the rotary methods using Gates Glidden.

Sae-Lim V *et al.*2000[25] studied the effectiveness of ProFile (.04 taper) rotary instruments in removal of obturating material and concluded that rotary instrumentation has been shown to be more effective than hand files in removing gutta-percha.

Imura N *et al.* 2000[26] compared the ability of two engine driven instruments (Quantec and Profile) and Hand files in removing gutta-percha

using a stereomicroscope to assess the remaining filling residue and found that no method was effective in achieving a clean canal

Hülsmann M *et al.*2004[27] evaluate the efficacy, cleaning ability and safety of FlexMaster, GT Rotary, Protaper and Hedström files with and without solvents and found out that Protaper and Flexmaster were comparatively better than other system and the use of solvent allows easy and faster removal of obturation material.

Ezzie E *et al.*2006[28] studied the effect of retreatment techniques for a resin-based root canal obturation material and inferred that Resilon is easily removable compared to gutta-percha

de Oliveira DP *et al.*2006[29] compared the remaining filling material and working time when removing gutta-percha/AH 26 and Resilon/Epiphany from root filled extracted teeth using chloroform and two different rotary systems (K3 and Liberator files). They came to the conclusion that Resilon/Epiphany was effectively removed with K3 or Liberator rotary files than gutta-percha.

Schirrmeister JF *et al.*2006[30] evaluated the ability of hand and rotary instrumentation for removal of vertically compacted Epiphany and gutta-percha during retreatment. The study conclusion was that vertically compacted Epiphany in combination with Epiphany Root Canal Sealant was removed more proficiently than gutta-percha and AH Plus sealer. Hedström files were more rapid than RaCe rotary instruments.

Schirrmeister JF *et al.*2006[31] compared the effectiveness of hand files and FlexMaster, Protaper, and RaCe rotary instruments for removing gutta-percha in curved root canals during retreatment by measuring the area of remaining obturation material and found that RaCe system is an efficient and safe in removing gutta-percha from curved root canals.

de Carvalho Maciel AC *et al.* 2006[32] compared automated and manual instrumentation techniques for removing filling material from root canal walls during root canal retreatment and deduced that photomicrographic method by epiluminescence was more effective than radiographic method and that rotary system was more effective than manual ones.

Gergi R *et al.*2007[33] analysed the efficacy of Protaper files and EndoRace files in gutta-percha removal and concluded that neither of the methods attained clean canals.

Cunha RS *et al.*2007[34] assessed the obturation removal and re-instrumentation working time of canals filled with Resilon/Real Seal in comparison with canals filled with gutta-percha/AH Plus and inferred that Resilon was better removed from the canal than the gutta-percha cones and the AH Plus regardless of time factor.

Lin ZM *et al.*2007[35] evaluated the sealing ability of Resilon after retreatment using K files and Profile and by viewing under scanning electron microscope for microleakage and concluded that Resilon can be used for retreatment, but it still allowed microleakage.

Hassanloo A *et al.* 2007[36] in a study assessed the efficacy of retreatment of canals filled with the Epiphany System with and without solvent, with reference to the extent of canal enlargement during retreatment. They concluded that Epiphany System was retreatable with and without chloroform, as compared to gutta-percha and AH Plus sealer.

Saad AY *et al.*2007[37] evaluated the effectiveness of removal of Gutta-percha and its sealer by rotary instruments, Protaper and K3 in comparison with hand instrument, Hedstrom files by comparing the time required for removal and the apical extrusion of debris and came to the conclusion that Protaper and K3 took less time for removal than Hedsrom files and noticed not much difference in the apical extrusion of debris in any of the systems.

Govila S *et al.* 2007[38] in a review article summarised the application of Cone beam computed tomography in acquiring three-dimensional images of periapical lesions and, mandibular canal. The review states that three dimensional anatomic and pathological observations improve the treatment outcome as well, since it allows single exposure there is slight decrease in the radiation exposure. Its inherent quickness in volumetric data acquisition and potential for reducing the cost of CT also has been mentioned.

Gu LS *et al.*2008[20] evaluated the efficacy of the Protaper Universal rotary retreatment system for gutta-percha (GP) removal from root canals, and concluded that among all test techniques of removal of GP like use of Protaper retreatment files, Gates Glidden, Hedstrom files and solvents left GP/sealer remnants within the root canal. The Protaper Universal rotary retreatment

system proved to be an efficient method of removing GP and sealer from maxillary anterior teeth.

Giuliani V *et al.*2008[39] studied the performance of the Protaper Universal System rotary retreatment system and of Profile 0.06 and hand instruments (K-file) in the removal of Gutta-percha and proved the rotary instruments to be fast and efficacious than hand instruments even though no system showed complete removal of obturation material.

Somma F *et al.*2008[40] in a study compared the effectiveness of the Mtwo R, Protaper retreatment files and a Hedström manual technique in the removal gutta-percha, Resilon and EndoRez during retreatment and concluded that all instruments left remnants of filling material and debris on the root canal walls irrespective of the root filling material used. The use of retreatment Ni-Ti rotary files to remove filling material quickly should be followed by hand instrumentation to refine and complete its removal and to obtain better canal wall cleanliness especially in the apical third further increasing the size of apical preparation. They also found out that, to minimize apical extrusion of debris, Ni-Ti rotary instruments should be used 1 to 2 mm short of the working length.

Bodrumlu E *et al.*2008[16] in a study evaluated the ability of three techniques in removing laterally compacted Resilon/Epiphany and gutta-percha/AH Plus from straight and curved canals during retreatment and established that Resilon/Epiphany filling removal left fewer remnants with

faster removal than gutta-percha/AH Plus using a Gates Glidden drill with or without chloroform in both straight and curved canals.

Hammad M *et al.*2008[41] measured the remaining volume of different filling materials like gutta-percha and TubliSeal sealer, EndoRez points and EndoRez, RealSeal points and RealSeal sealer, gutta-percha point and GuttaFlow sealer after removing with Protaper retreatment files or hand K-files and they concluded that all tested filling materials were not completely removed during retreatment by using hand or rotary files and gutta-percha was more proficiently removed by using hand K-files.

Taşdemir T *et al.*2008[42] compared the efficacy of three rotary instruments Protaper, R-Endo, Mtwo and hand instrument Hedström files, to remove gutta-percha and AH Plus sealer and identified that complete removal of materials did not occur with any of these instrument systems where as Protaper left less material when compared to the Mtwo instruments

Taşdemir T *et al.*2008[43] compared the ability of Mtwo and Mtwo retreatment files in removing gutta-percha and Resilon and found that there was no significant difference between the two removal methods.

Barletta FB *et al.*2008[44] compared the amount of residual gutta-percha in canals after removal using Gates-glidden, K file and Protaper using CT and summarised that CT to be a reliable method to assess the retrievability of obturation material

Só MV *et al.*2008[45] evaluated the efficacy of Protaper Universal rotary retreatment system and hand files for filling material removal during retreatment and the influence of sealer type on the presence of filling debris in the re-instrumented canals and found out that none of the methods achieved clean canals and the apical third of canals to be the least retreatable area of canal.

Schäfer E *et al* 2008[46] compared the performance of Alpha-File, FlexMaster, Mtwo, ProFile and RaCe by means of a computer-driven testing device and discerned that Mtwo and RaCe displayed the greatest cutting efficiency.

Çelik Ünal G *et al.*2009[47] compared the adeptness of conventional and ProFile, R-Endo or Protaper Universal retreatment files when removing gutta-percha root fillings in curved root canals and found out that Protaper retreatment file were less effective in removal of Gutta-percha than Profile and Hand files.

Hammad M *et al.* 2009[48] measured percentage of volume of voids and gaps in root canals obturated with different obturation materials - gutta-percha and TubliSeal sealer, EndoRez points and EndoRez sealer, RealSeal points and RealSeal sealer, and a gutta-percha point and GuttaFlow sealer by using micro–computed tomography (micro-CT) and showed that none of the tested filling materials provided a gap-free or void-free root canal filling, and that gutta-

percha used with TubliSeal exhibited less voids and gaps than the other tested materials.

Anil Kumar G *et al.*2009[10] in this study evaluated the amount of residual filling material on the canal walls in root canals filled with gutta-percha or Resilon and retreated using the Protaper treatment files and inferred that even though gutta-percha and AH plus sealer do not adhere as well to the canal wall as epiphany, removal of epiphany left significantly less filling material than removal of gutta-percha and AH plus. The Resilon-Epiphany system is retreatable leaving cleaner dentinal walls in comparison to gutta-percha and AH Plus.

Zarei M *et al.* 2009[12] in a study to compare the retreatability of gutta-percha and Resilon, the amount of residual material and time of retreatment was determined in each group at three levels in the canal, using RaCe and came to conclusion that orthograde retreatment of Resilon was less efficient than that of gutta-percha leaving residual material in the canal.

Pirani *et al.*2009[2] assessed the root canal wall morphology under scanning electron microscopy magnification after removal of warm vertically condensed gutta-percha and Thermafil gutta-percha with AH plus sealer removed using ultrasonic tips, nickel-titanium (Ni-Ti) rotary instruments, and hand K-files. The study proved that none of the methods removed obturation material from the canals, especially apical third.

Shrestha D *et al.* 2010[49] in an article had reviewed the adhesive concept of bonding of Resilon to root dentin and stated that it can be used as an alternative to gutta-percha even though the material lacks the required properties of an ideal root canal filling material. And also, mentioned that it is necessary to improve the mechanical and chemical properties of the material to achieve optimal bonding to root dentin, taking into consideration the heterogenicity in composition of dentin and the anatomical complexity. rotary system and gutta-percha took lesser time than for Resilon

Marfisi K *et al.*2010[9] evaluated the efficacy of Protaper Retreatment files, Mtwo Retreatment files and Twisted Files in removal of gutta-percha and Resilon from straight root canals and proved that Mtwo Retreatment files required less time when compared to other instruments for removal of the root filling material. Removal of Resilon from the canal walls was significantly better than gutta-percha, irrespective of the rotary instruments used.

Khatavkar RA *et al.*2010[15] elaborates on the Resilon-Epiphany obturation system and its bonding ability over gutta-percha making it a good obturating material and the paradigm shift in obturation with the introduction of newer obturation materials with improved properties than Gutta percha.

Ramzi H *et al.*2010[50] in a study compared the retreatment efficacy of Mtwo file and Mtwo retreatment system, with chloroform and with Endosolv R in three groups and found out that no technique achieved a complete removal of obturation material from the canals and the canals retreated using rotary along with Endosolv R created a more cleaner canal compared to the other

groups. In all the techniques, the apical third proved to be the least cleanable even though Endosolv R group achieved a comparatively cleaner surface.

Duarte MA *et al.*2010[51] compared the efficacy of manual and rotary Protaper retreatment files in removal of gutta-percha and its sealer with the help of microscopes and radiographs and concluded that the apical third of root canals was the most difficult to be cleaned and microscopic evaluation was comparatively efficient in the identification of remaining filling material in the canal.

Bramante CM *et al.*2010[52] evaluated the heat release, time required, and cleaning efficacy of MTwo and Protaper Universal Retreatment systems in comparison with hand instrumentation and concluded that Protaper UR and MTwo R caused the greatest and lowest temperature increase on root surface, respectively even though all techniques left filling debris in the root canals

Luiz F F *et al.* 2011[8] ascertained the ability of ProFile, GT, Protaper, Race and K3 rotary instruments compared with hand K-files for removal of gutta-percha during retreatment and concluded that GT, ProFile, Protaper and K3 were more effective in removing gutta-percha than manual and Hero instruments.

Aguiar CM *et al.*2011[53] assessed the effectiveness of the Protaper Universal Retreatment system and manual files in endodontic retreatment using two gutta-percha solvents, Orange Oil and Eucalyptol and inferred that K-file and Hedström files achieved better results than the ProTaper Universal

Retreatment system in the removal of filling material, regardless of the solvent solution used.

Reddy S *et al.* 2011[54] evaluated the cleanliness of root canal walls after retreatment using two rotary retreatment files (Protaper Universal retreatment system and R-Endo retreatment files) to hand instruments in severely curved canals obturated with gutta-percha and an epoxy resin based sealer and zincoxide eugenol based sealers and concluded that the R-Endo system removed the obturation material much better when compared to the Protaper retreatment file system, even though none of the systems used produced a thoroughly cleaned root canal.

Shanahan DJ *et al.*2011[55] has described Resilon obturation points after analysing various literatures related to the invitro studies with Resilon, mostly leakage-type studies. In this article, they have proposed Resilon as a replacement obturation material to the gold standard Gutta-percha obturation, considering its typical property of bonding to dentinal walls and ability to form 'monoblock' providing a perfect seal of root canal obturation.

Shenoy VU *et al.*2011[56] in a review article highlighted the advantages of Resilon over the traditionally used gutta-percha, emphasizing its adhesive property through monoblock formation.

Shwaliya *et al.*2011[57] compared the fracture resistance of teeth after rotary instrumentation with Protaper instruments by subjecting the obturated teeth to the mechanical test in a universal testing machine and the maximum

load at the fracture point revealed that Resilon system increased resistance to fracture than gutta-percha.

Al azzawi *et al.*2011[11] compared the removal efficacy of gutta-percha and Resilon using the Protaper retreatment files by visually examining the canals of split tooth and photographing and analysing in adobe photoshop software and found that canals obturated with gutta-percha had a cleaner canal when compared with Resilon obturated canals.

Marques da Silva B *et al.*2012[59] studied the ability of Protaper, D-RaCe, and Mtwo retreatment files along with and without additional files of the respective systems and found out that there was no much difference in the removal of material even with the use of additional files.

Kfir A *et al.*2012[60] in a study evaluated the removal efficiency of Gutta-percha and AH Plus using chloroform and Hedstrom files, SafeSider files, using a NiTi Peeso reamer and reciprocating file, with or without chloroform, or Protaper Universal retreatment files (D2, D3) with or without chloroform and assessed it using radiographs and microscopes. They concluded that none of the methods adopted created a clean canal and that the microscopic method of evaluation was superior to radiographic method in detecting the remaining filling material in the canal.

Kumar MS *et al.*2012[61] conducted a study to demontrate the efficacy of Protaper Universal rotary retreatment system with or without solvent and stainless steel hand files, by measuring the remaining debris ratio and the time

required for removal of obturation material and found out that no technique achieved complete removal of material and Protaper was faster in removal compared to the hand file techniques.

Economides N *et al.*2012[62] compared the push-out bond strength of Smartseal with gutta-percha/AH26 to calculate the bond strength and found out that Smartseal and Gutta-percha showed similar bond strengths and adhesion to dentin irrespective of single cone or lateral condensation technique.

Mohebbi P *et al.*2012[63] **–** assessed the efficacy of Mtwo retreatment files and Protaper retreatment files in removing the Resilon/Epiphany system with or without chloroform during retreatment and concluded that Protaper and Mtwo retreatment file systems were similar in removal efficacy for retreatment in the whole root canal system where as Protaper retreatment files along with solvents were more efficacious in removal of obturation material in the apical third of root canal.

Akhavan H *et al.*2012[64] did a microscopic evaluation of residual gutta-percha and sealer in the root canal after removal using Mtwo and D-Race retreatment systems and inferred that both systems were equally efficient in removal of obturation material.

Jayasentil *et al.*2012[65] evaluated the efficacy of Protaper universal retreatment files and R-Endo in comparison to manual technique in removing Gutta-percha obturated with two sealers using optical stereomicroscope and

proved hand instrumentation to be better than the rotary systems in achieving cleaner canals.

Ma J *et al.* 2012[66] did a micro–computed tomography to estimate the amount of remaining root filling material in oval canals filled by gutta-percha in lateral condensation and continuous wave compaction using Protaper retreatment files with and without solvents and ascertained that none of the removal methods were efficient in obtaining clean canals and canals obturated with continuous wave compaction left more residue.

Dadresanfar *et al.*2012[67] compared the efficacy of Mtwo R and Protaper retreatment files in removing the Resilon/Epiphany system with or without chloroform during retreatment using radiography; a stereomicroscope and SEM and found out that Protaper/solvent was better in the apical third; however, when considering the whole canal, Mtwo R and the Protaper D series had the similar efficacy.

Lotfi M *et al.*2013[68] reviewed existing literature from May 2004 to April 2012 which studied the physical and chemical properties of Resilon and they also reviewed some leakage studies to conclude that the resilon obturation material has the property to bind to the canal walls preventing leakage, also has antibacterial and antifungal properties, making it an acceptable material for obturation.

Pathivada L *et al.*2013[18] in an review article had introduced the newer obturation material, Smart seal, which is based on polymer technology and had

mentioned the hydrophilic property of this obturating points which can absorb surrounding moisture and expand resulting in filling of voids and spaces, helping in achieving a better seal of obturation.

Didato A *et al.*2013[69] studied the lateral hygroscopic expansion of CPoint with gutta-percha and found out that gutta-percha showed no time dependent expansion whereas CPoint did.[22]

Yadav P *et al.*2013[70] did an in vitro CT comparison of gutta-percha removal with two rotary systems and Hedstrom files by analyzing the images to calculate the remaining volume of obturation material in the canal after removal using Protaper retreatment files, Mtwo retreatment files or Hedstrom files and concluded that rotary files to be more efficient in removing obturation materials than manual files whereas no system was found to be effective in complete removal of the obturation material.

Wasnik *et al.*2013[71] compared the effectiveness in retreating gutta-percha obturated root canals using Profile, with and without the aid of chloroform, to hand files with chloroform, with the help of, photograph after splitting the teeth longitudinally and came to the conclusion that although all the retreatment method were able to remove the obturation material, achieving clean canals were impossible.

İriboz E *et al.*2014[72] evaluated the effectiveness of the Protaper and Mtwo retreatment systems for removal of resin-based obturation techniques during retreatment and found out that both systems were effective in removal

of resin based materials than gutta-percha and Protaper was faster in removal than Mtwo retreatment systems.

Arora S *et al.* 2014[73] studied the homogeneity of filling in obturation of a novel polyamide polymer based obturating system, Smartseal system and Gutta-percha and sealer in simulated lateral canals. The study was done in calcified and decalcified samples of teeth where after obturation using Smart seal system and Gutta-percha they were observed using Cone beam computed tomography and digital radiography respectively, for the linear extension and area of the obturation material along with its sealer into lateral canals. They concluded that the polyamide polymer based obturation material showed better efficiency in obturation with the better adaptation and penetration of sealer into simulated lateral canals.

Dhillon JS *et al.*2014[74] demonstrated the efficacy of Pro Taper and Pro Taper Retreatment instruments in the removal of gutta-percha during retreatment of straight root canals and found out that both Protaper files and Protaper retreatment files were equally effective in removing gutta percha during retreatment.

Alves FR *et al.*2014[75] compared the efficacy of Protaper Universal, ProTaper Universal Retreatment, Mtwo and Mtwo Retreatment systems in the removal of Gutta-percha from apical third by assessing the area of remaining material in apical 5mm of all canals and inferred that all the systems were comparatively equal in efficacy in removal of obturation material.

Asheibi F *et al.*2014[76] evaluated the effectiveness of ProTaper rotary files with ProTaper retreatment and K-files in the removal of Resilon or gutta-percha (GP) from canals filled either by cold lateral condensation or thermal obturation using micro-CT. In roots filled with thermal obturation, Resilon was remaining more than gutta-percha and in obturation using thermal technique less material remained than cold condensation except Resilon retreated using ProTaper retreatment and K-files.

Niemczyk SP *et al.* 2014[77] in his article has explained the use of cone beam computed tomography by illustrating the various clinical case scenarios, including anomalous root morphologies, additional canal spaces and insights into eccentric periapical pathologies. According to the study, the use of Cone beam computed tomography has become useful in retreatment situations where the normal anatomy of pulp chamber has been altered or destroyed and where conventional radiographs fail, for excavation in the proper dimension and direction to facilitate a more thorough treatment delivery.

de Azevêdo Rios M *et al.* 2014[78] compared the retreatment efficiency of gutta-percha by two reciprocating rotary systems, WaveOne system and Reciproc system, in comparison to Protaper universal retreatment rotary systems, by measuring the remaining material in canal after removal, with the help of microscopic magnification and found out that both systems were as efficient as Protaper retreatment system in removing the obturation material.

Soares C *et al.*2015[79] reviewed articles published in the period from 2001 to 2014, to identify the most efficient method for extirpation of Resilon

root fillings and to compare the speed and efficacy of Resilon and gutta-percha root filling removal and concluded that the ProTaper (manual or rotatory) system in combination with chemical solvents is the most efficient method for removing Resilon root filling and retreatment of Resilon is more rapid and associated with less remnants of debris than Gutta-percha.

Prado RG *et al.*2015[80] compared the effectiveness of R-Endo, Mtwo Retreatment, D-RaCe, and ProTaper by measuring the remaining material in the canal after removal and also the time for removal. They came to the conclusion that all systems were almost similar in cleaning the canal with the Mtwo system requiring lesser time for removal than R-Endo, D-RaCe, and ProTaper in sequence.

Gokturk H *et al.*2015[81] in a study evaluated the residual root canal filling material after retreatment of root canals using stainless steel hand files, Mtwo R, R-Endo, ProTaper Universal Retreatment, and D-RaCe systems. They noticed the most residual gutta-percha and sealer in the apical third compared to the coronal and middle thirds. Nickel-titanium rotary retreatment instruments were faster than Hedström files in removal of obturation material, but had a higher risk of instruments fracture.

Beshr K *et al.*2015[82]assessed retreatment efficacy with K3, Protaper universal or R-Endo rotary systems with the help of computed tomography imaging to assess the percentage of residual filling material (Gutta-percha, Realseal or EndoRez). The apical third was the most difficult to be cleaned, with most remaining filling material compared with the middle and cervical

thirds. Retreatment of root canal filled with Real seal and Endo-Rez showed lesser remaining material than retreatment of gutta percha and AH plus sealer.

Hegde V *et al.*2015[83] compared the apical sealing ability of a novel Smart-Seal System, Resilon, and conventional Gutta-Percha system using a bacterial leakage model and concluded that the hydrophilic obturations of the root canal shows a better resistance to bacterial leakage as compared to hydrophobic obturations.

Hegde V *et al.*2015[84] evaluated the fracture resistance of roots obturated with three hydrophilic systems - CPoint system, Resilon/Epiphany system, and EndoSequence BC sealer; and one hydrophobic gold standard gutta-percha/AH Plus system by recording the force required to fracture the obturation point from root canal, using a universal testing machine and concluded that all the hydrophilic obturation system showed higher fracture resistance than the hydrophobic gutta-percha obturation.

Singh R *et al.* 2015[85] in a study conducted to compare the efficacy of R endo retreatment files and Mtwo retreatment files with hand files, in removing gutta-percha from canals analysed using photograph, found that Mtwo and R Endo retreatment files to be more efficient than the hand instrumentation techniques.

Jaiswal *et al.* 2015[86] assessed the gutta-percha removal efficiency of Protaper-R, R-Endo, Mtwo and Hedstrom files using a computer image analysis program and found that hand files obtained a cleaner canal in

comparison with rotary files even though retreatment was possible in lesser time with rotary system.

Baig AR *et al.*2016[87] in a review article described an ephemeral synopsis of smart seal, a hygroscopic obturating system with a reference of numerous studies associated with it. The sealing of root canal system is based on polymer technology with its hydrophilic property in which the material can absorb moisture from within the canal and associated sealer to expand within the canal system causing the adjunct sealer to be pushed in to the dentinal tubules and lateral canals which creates a better seal of the root canal space, thus making this material an acceptable material for root canal obturation.

Akbulut MB *et al.* 2016[88] studied the efficacy of Twisted File Adaptive, Reciproc, and ProTaper Universal Retreatment System instruments for retreatment using Cone beam computed tomography and also measuring the time required for removal with each systems and found out that root canal filling was more efficiently removed by using Reciproc and ProTaper UR instruments than TF Adaptive instruments and hand files and that ProTaper UR and Reciproc systems required shorter periods of time for retreatment.

Khedmat S *et al.*2016[89] in a study on ProTaper retreatment (ProTaper R) and Mtwo retreatment (Mtwo R) files in removing gutta-percha and GuttaFlow from endodontically treated straight root canals. The time required to remove the material as well as the amount of remaining material in the canal after removal was calculated with the help of cone beam computed tomography images and found out that there was lesser amount of material left in the canals

retreated with Protaper retreatment systems and Mtwo retreatment system took lesser time for removal than Protaper retreatment systems.

Hassan N *et al.*2016[90] had studied the effect of different aging periods on the bond degradation resistance of the water-expandable endodontic obturation points/dentin interface with gutta-percha sealer dentin interface and concluded that bonding quality during the initial setting period of CPoint/Endosequence obturating system was neither affected nor deteriorated with aging and CPoint/Endosequence obturating system was better than Gutta-percha/AH-Plus in bond degradation resistance.

MATERIALS AND METHODS

MATERIALS USED IN THE STUDY

a. Saline - Baxter, India Pvt. Limited, Tamil Nadu, India.
b. 5.25% NaOCl - Azure Laboratories Pvt. Ltd., Maharastra, India.
c. 17% EDTA - AvuePrep, Dental Avenue Pvt.Ltd., Maharastra, India.
d. Protaper Gutta percha of F2 size and #20 & 25, 2% guttapercha accessory cones - Dentsply Maillefer, Switzerland.
e. AH Plus root canal sealer - Dentsply DeTrey, USA.
f. Resilon obturation points - #25, 6% and #20 & #25 2% as accessory cones - Sybron Endo, Orange, CA, USA
g. Real Seal SE sealer - Sybron Endo, Orange, CA, USA
h. CPoint – F2 size Propoint - EndoTechnologies, LLC, Shrewsbury, MA
i. EndoSequence BC sealer - Brasseler, Savannah, Georgia, USA.
j. Cavit - 3M ESPE, Germany.
k. Paper points – Dentsply Maillefer, Switzerland.

Equipments/Instruments used in the study

a. Micromotor straight hand piece – NSK, Nakanishi, Japan.
b. Diamond Disc – SS White, New Jersey, USA.
c. High Speed airotor hand piece – NSK, Nakanishi, Japan.
d. Metal Scale – Marsman, India.
e. EndoBloc – Dentsply, Maillefer, Switzerland.
f. Endo access bur – Dentsply, Maillefer, Switzerland.

g. K files - No. 10, 15 - Mani Dental. Inc., Japan.
h. X-Smart Plus – Dentsply, Maillefer, Switzerland.
i. Protaper NiTi rotary instruments SX, S1, S2, F1, F2 - Dentsply, Maillefer, Switzerland.
j. Spreaders 15, 20, 25 - Mani Dental. Inc., Japan.
k. Protaper retreatment file – D1, D2, D3 - Dentsply Maillefer, Switzerland.
l. MTwo retreatment files – R1, R2, R3 - VDW, Munich, Germany.
m. CBCT – CS9300 equipment - Carestream Healthcare India Pvt. Ltd.

Inclusion criteria - Single rooted mandibular premolars, freshly extracted for orthodontic purposes, stored in saline and used within three months of extraction.

Exclusion criteria - Fractured teeth, more than one root canal, resorption, open apices, caries, obturated teeth, curved rooted teeth.

METHODOLOGY

Specimen preparation

Sixty single rooted mandibular premolars freshly extracted for orthodontic purpose were collected and disinfected in 0.5% Chloramine-T for 1 hour and stored in saline (Baxter, India Pvt. Limited, Tamil Nadu, India.) till use (was used within three months of extraction). Diagnostic X-ray were taken to confirm the existence of a single straight canal, fully formed apex and no

signs of internal resorption, calcification or previous endodontic therapy or caries, restoration or presence of dentin pins. Soft tissue and calculus were removed mechanically from the root surface. They were decoronated using a diamond disc (SS White, New Jersey, USA) to attain a 15mm. root length. Working length were determined with size #15 K-file (Mani Dental. Inc., Japan), by inserting the file into the canal until the tip of the file is just visible at the apical foramen and reducing 1mm from this length from coronal reference point to the tip. In all teeth root canal treatment was initiated. Root canal cleaning and shaping was done in crown down technique using Protaper Ni-Ti rotary system (Dentsply, Maillefer, Switzerland). Patency of the canal was maintained throughout the procedure by passing #10 K-file (Mani Dental. Inc., Japan) approximately 1mm through the apex.[9,10,11]

Cleaning and shaping of the canal was carried out using Protaper NiTi rotary system - Sx, S1, S2, F1, F2 (Dentsply, Maillefer, Switzerland). And the canals were enlarged up to F2 at working length. During instrumentation, all canals were irrigated between each instrument change with 5ml of 5.25% NaOCl (Azure Laboratories Pvt. Ltd., Maharastra, India). The smear layer was removed using 5ml of 17% EDTA (Azure Laboratories Pvt. Ltd., Maharastra, India) for one minute, followed by a final rinse of 2ml of 5.25% sodium hypochlorite and finally with 5ml saline following the irrigation protocol. The canals were then dried with paper points (Dentsply Maillefer, Switzerland) and the obturation was done by cold lateral condensation.[9,10,11,116]

Groups used in the study

Tooth were randomly selected and divided into six groups of 10 teeth each.

Group I - obturated with Gutta percha and AH Plus and retreatment with Protaper retreatment file system

Group II - obturated with Gutta percha and AH Plus and retreatment with Mtwo retreatment file system

Group III - obturated with Resilon and Real Seal SE and retreatment with Protaper retreatment file system

Group IV - obturated with Resilon and Real Seal SE and retreatment with Mtwo retreatment file system

Group V - obturated with CPoint and Endosequence BC sealer and retreatment with Protaper retreatment file system

Group VI - obturated with CPoint and Endosequence BC sealer and retreatment with Mtwo retreatment file system

In Group I and Group II, the canals were filled with Protaper Gutta percha of F2 size (Dentsply Maillefer, Switzerland) and AH Plus sealer (Dentsply DeTrey, USA) using lateral condensation technique using accessory cone (Dentsply Maillefer, Switzerland) with the help of spreaders (Dentsply Maillefer, Switzerland), and sealed using a heated instrument at the level of orifice of all canals. The canals in Group III and Group IV were coated with

Real Seal SE sealer (Sybron Endo, Orange, CA, USA) with a previously selected Resilon master cone (Sybron Endo, Orange, CA, USA), lateral condensation was followed with accessory cones (Sybron Endo, Orange, CA, USA), immediately light-cured for 40 seconds and the excess is trimmed off using a bur.[11,14,29] In Group V and Group VI canals were filled using the CPoint (EndoTechnologies, LLC, Shrewsbury, MA) self-sealing water expandable obturation pointalong with Endosequence BC sealer(Brasseler, Savannah, Georgia, USA.), after cleaning and shaping, without drying the canal[17,18]. Hydration from sealer and dentin-derived moisture helps the CPoints expand, conforming to canal irregularities, pressing the companion hydrophilic bioceramic sealer, Endosequence BC sealer into concavities, lateral portals of exit and the tubules of the dentin walls.[108] Then the excess is trimmed off using a bur. The teeth were radiographed to confirm the adequacy of the root filling. After placing a temporary restoration of Cavit (3M ESPE, Germany), each tooth stored in a humidor at 37°C for 2 weeks to allow the sealer to set completely.[9,11]

CBCT Image Acquisition & Processing

All the specimens were imaged using Sirona CBCT machine from DMD imaging system, Dental and Maxillofacial diagnostics, Ghaziabad, Uttarpradesh.

CBCT images for all teeth were obtained, with CS9300 equipment (Carestream Healthcare India (P) Ltd) in the high resolution dental mode at 74

kV, 2.5mA. A single scout image, *i.e.* lateral view was taken in accordance with the teeth position, and a 360° scan was acquired afterwards. The total scan time was 20s. The time required for the reconstruction of volumetric images after the sample's complete exposure was approx. 1 min.

Study images were reconstructed from the volumetric dataset, in planes perpendicular to the selected tooth axes. True and oblique axial, coronal and sagittal images with a thickness of 0.09mm and an interval of 0.09mm were obtained.

Obtained images were viewed using CS 3D imaging v3.5.7 software, Carestream Health. Inc, Internal Version 3.5.7.0(10/10/2014). Image assessment performed by a calibrated orthodontic post-graduate student and verified by a maxillofacial radiologist using the CBCT software tools.

For the assessment of volume of the root canal cavity in pre-treatment scan and residual endodontic restorative material in post-treatment scan, the scans were co-ordinated in all the three planes along the long axis of the tooth i.e. coronal, sagittal and axial plane to minimize any error.

Retreatment technique:

All temporary cements were removed by straight fissure bur. All rotary instruments were used in a crown-down technique on a low-torque rotary engine driven motor – Xsmart Plus (Dentsply Maillefer, Switzerland) in the preset torque levels and constant speed recommended by the manufacturer for

each type of instrument. For all teeth from Group I, III and V retreatment by removal of obturation materials were initiated using Protaper retreatment files (Dentsply Maillefer, Switzerland.), used in a brushing action according to the instructions of the manufacturer - D1 (30/.09) for removing materials from the coronal third, D2 (25/.08) for removing materials from the middle third, and D3 (20/.07) for removing material from the apical third.[11,20] The working length were regained gradually using a pecking motion. The obturation materials from all the teeth from remaining groups – II, IV and VI were removed using Mtwo retreatment files (VDW, Munich, Germany) in a simultaneous technique to the working length until the wall of canal is smooth and clean till size R2 (size 25, 0.05 taper) in a brushing action with lateral pressing movements. Progression of the rotary file were performed by applying slight apical pressure and frequently removing the files to inspect the blades and clean the debris from the flutes.[19,52] All the root canals were constantly irrigated with 2.5ml of 5.25% NaOCl, 10ml of EDTA solution and 5ml of NaOCl alternately with the final irrigation of 5 ml of saline, according to the irrigation protocol, in between each file change.[9,11,115]

The criteria for completion of retreatment is the presence of clean filings, no evidence of filling material on the flutes of files or paper point and smooth canal walls. To achieve standardization during retreatment, one set of instruments were used per tooth.[11,20,39]

Analysis of remaining filling material using CBCT

The remaining filling material on canal walls were evaluated through CBCT. The. axial, frontal and sagittal sections at 1.25, 2.50, 3.75, 5, 6.25, 7.50, 8.75 and 10 mm were obtained after adjusting the appropriate parameters for scanning. Images were analysed and the amount of remaining filling material will be calculated with AutoCad software, version 2007 (Autodesk, San Rafael, CA, USA).

The volume of the canal and of the residual filling material were recorded, and the volume percentage of remaining filling material on canal walls was calculated with the following equation:

Volume % of remaining filling material = volume of remaining filling material/total volume of material in canal before removing × 100

Statistical analysis: The data was analysed by Statistical Package for Social Sciences (SPSS 16.0) version. ANOVA (Post hoc test) followed by Dunnet t test applied to find statistical significant between the groups. Paired ‘t’ test applied to find statistical significant before and after treatment. P value less than 0.05 ($P<0.05$) considered statically significant at 95% confidence interval.

RESULTS & OBSERVATIONS

RESULTS

Table 1 : Shows the mean volume of obturation material in the root canal before removal using retreatment file system, after removal using retreatment file system and the mean volume percentage of remaining filling material.

This table shows that the least volume percentage is in Group III (16.35±2.69%) followed by Group IV, followed by group I, II, V and VI, with the maximum volume percentage in Group VI (29.67±2.34%).

Table 2 : This table shows the comparison of mean values before retreatment and after removal of obturation material using retreatment file system within the six groups.

($P<0.05$ significant compared before retreatment with after removal, within the groups)

There is statistically significant difference in the mean volume in all groups after removal of obturation material.

Table 3 : This table shows the comparison of mean values of volume of obturation material before retreatment and after removal between group I and II.

($P>0.05$ no significant difference compared Group-I with Group-II)

There is no statistical significance in the mean values of volume of after removal between group I and II.

Table 4 : shows the comparison of mean values of volume of obturation material before retreatment and after removal using retreatment file systems between group III and IV.

(P>0.05 no significant difference compared Group-III with Group-IV)

There is no statistical significance in the mean values of volume of after removal between group III and IV.

Table 5 : shows the comparison of mean values of volume of obturation material before retreatment and after removal using retreatment file systems between group V and VI.

(P>0.05 no significant difference compared Group-V with Group-VI)

There is no statistical significance in the mean values of volume of after removal between group V and VI.

Table 6 : shows the comparison of mean values of volume of obturation material before retreatment and after removal between group I with all other groups.

(*P<0.05 significant - compared Group-I with other groups).

There is no statistical significance in the values in comparison with Group II and IV where all other groups show statistically significant different results.

Table 7 : shows the comparison of mean values of volume of obturation material before retreatment and after removal between group II with all other groups.

(*P<0.05 significant compared Group-II with other groups)

There is no statistical significance in the values in comparison with Group I and IV whereas all other groups show statistically significant different results.

Table 8 : shows the comparison of mean values of volume of obturation material before retreatment and after removal between group III with all other groups.

(*P<0.05 significant compared Group-III with other groups)

There is no statistically significant differences in the mean values between group IV whereas all other groups show statistically significant different results.

Table 9 : shows the comparison of mean values of volume of obturation material before retreatment and after removal between group IV with all other groups.

(*P<0.05 significant compared Group-IV with other groups)

There is no statistically significant differences in the mean values in comparison with Group I, II and III whereas there is statistically significant differences in the mean value between group V and VI.

Table 10 : shows the comparison of mean values of volume of obturation material before retreatment and after removal between group V with all other groups.

(*P<0.05 significant compared Group-V with other groups)

There is no statistically significant differences in the mean values between group VI whereas there is statistically significant difference in the mean values with all the other groups.

Table 11 : shows the comparison of mean values of volume of obturation material before and after removal between group VI with all other groups.

(*P<0.05 significant compared Group-VI with other groups)

There is no statistically significant difference in the mean values between group V, whereas there is statistically significant difference in the mean values with all the other groups.

Table 12 : shows multiple comparison of mean volume values between all the groups

(*P<0.05 significant compared Group-I with other groups, $^{\#}$P<0.05 significant compared Group-II with other groups, $^{\$}$P<0.05 significant compared Group-III with other groups, $^{\|}$P<0.05 significant compared Group-IV with other groups)

The least mean value is for Group II (5.81±0.98$^{*,\#}$ mm^3) and the highest is for Group VI (11.00±0.90$^{*,\#,\$,\|}$$mm^3$)

Group I shows statistically significant difference in mean volume after removal with groups III, V, VI

Group II shows statistically significant difference in mean volume after removal with groups III, V, VI

Group III shows statistically significant difference in mean volume after removal with groups I, V, VI

Group IV shows statistically significant difference in mean volume after removal with groups V, VI

Group V shows statistically significant difference in mean volume after removal with groups I, II, III, IV

Group VI shows statistically significant difference in mean volume after removal with groups I, II, III, IV

Table-13 : shows the Multiple comparisons of mean total percentage values between the groups

(*$P<0.05$ significant compared Group-I with other groups, $^{\#}P<0.05$ significant compared Group-II with other groups, $^{\$}P<0.05$ significant compared Group-III with other groups, $^{\|}P<0.05$ significant compared Group-IV with other groups)

Group I shows statistically significant difference in mean volume percentage after removal with groups III, V, VI

Group II shows statistically significant difference in mean volume percentage after removal with groups III, V, VI

Group III shows statistically significant difference in mean volume percentage after removal with groups I, V, VI

Group IV shows statistically significant difference in mean volume percentage after removal with groups V, VI

Group V shows statistically significant difference in mean volume percentage after removal with groups I, II, III, IV

Group VI shows statistically significant difference in mean volume percentage after removal with groups I, II, III, IV

OBSERVATIONS

The retrievability of three different obturation materials has been measured by calculating the volume percentage of the remaining material in the root canal after removal using the rotary retrieval systems.

The results show the highest retrievability for Group III (Resilon group removed using Protaper retreatment system) with the least mean volume percentage after removal as 16.35 ± 2.69 % and least retrievability for Group VI with the highest mean volume percentage as 29.67 ± 2.34 %.

The results show that the mean volume percentage of material in the root canal has significantly reduced after removal in all groups with the p value 0.001 ($P<0.05$ considered statistically significant in all groups)

Comparison between group I (obturated with Gutta-percha and AH Plus sealer removed by Protaper retreatment files) and II (obturated with Gutta-percha and AH Plus sealer removed by Mtwo rotary retreatment system) shows the mean volume percentage for group I was 19.71 ± 1.98% which was lesser than that of group II (21.00 ± 2.41%).

Comparison between group III (obturated with Resilon and RealSeal SE sealer removed by Protaper retreatment files) and IV (obturated with Resilon and RealSeal SE sealer removed by Mtwo rotary retreatment system) shows lesser mean volume percentage for group III (16.35 ± 2.69%) than IV (19.14 ± 2.95%).

Comparison between group V (obturated with CPoint and Endosequence bioceramic sealer removed by Protaper retreatment files) and VI (obturated with CPoint and Endosequence bioceramic sealer removed by Mtwo retreatment files) shows lesser mean volume percentage for group V (24.91 ± 2.66%) than VI (29.67 ± 2.34%).

There is no statistically significant difference in the mean volume percentage on comparison between group I and II, Group II and IV and Group V and VI.

From these results, it can be inferred that all the groups show significant difference in the remaining obturation material after removal with the two rotary systems with lesser amount of material left with Protaper retreatment file

removal than Mtwo retreatment file system removal even though there is no statistical significant difference in removal efficacy between the files.

It can also be inferred that the canals obturated with CPoints and Endosequence Bioceramic sealer were the most difficult to be cleaned with both Protaper and Mtwo rotary retreatment systems whereas the canals obturated with ResilonTM and RealSeal SE was comparatively cleaner than all the other obturation materials used with both rotary retreatment file systems.

DISCUSSION

In this study, the canals obturated with CPoints and Endosequence BC showed the maximum volume of remaining obturation material after removal with Mtwo retreatment file system and Protaper retreatment file system when compared to other groups obturated with Resilon™ and gutta-percha. Hence the study hypothesis that CPoint to be the most difficult obturation material to be removed from the root canal, during retreatment, was proved partially correct.

An endodontic therapy is a sequence of treatment for the infected pulp of a tooth which has associated pulp and/or periapical pathosis, which results in the elimination of infection and protection of the decontaminated tooth from future microbial invasion.[1]

In 1965 Kakehashi, Stanley and Fitzgerald conclusively stated that pulpal and endodontic problems are primarily related to microbial contamination of the root canal system. Since that time endodontology has increasingly focused on the ways and means of eliminating microorganisms from the entire root canal system.[91]

Rickert and Dixon's hollow tube theory in 1931, postulated that tissue fluids entering the root canal gets stagnated and formed toxic breakdown products which leached into the periapical tissues. This theory suggests the necessity of obturating dead spaces within the body. Once the canal system has been shaped and cleaned it should be obturated to prevent the entry of microorganisms to the root canal system from either the oral cavity, by failure

of coronal restoration or via the bloodstream through the process of anachoresis and to prevent the ingress of tissue fluid which can serve as a culture medium for any bacteria retained after treatment.[92]

According to Cohen success of endodontic treatment depends on the endodontic triad - Debridement, Disinfection and Obturation.[92] The success of endodontic treatment depends on thorough debridement of canal system of infected or necrotic pulp tissue, microorganisms and complete sealing of the canal space, thus preventing persistence of infection and/or reinfection of the pulp cavity.[1]

Apical periodontitis is a sequel to endodontic infection and manifests itself as the host defense response to microbial challenge emanating from the root canal system. The treatment of apical periodontitis, as a disease of root canal infection, consists of eradicating microbes or substantially reducing the microbial load from the root canal and preventing reinfection by orthograde root filling which has a high degree of success.[93]

The main goal in endodontic therapy is to recognize and remove the etiological factors. Debridement of the root canal by instrumentation, irrigation and removal of biofilm is considered an important factor to prevent and treat endodontic disease. The root canal morphology provides excellent conditions for a biofilm formation which is one of the main causes for endodontic reinfection.[94]

For primary endodontic therapy, several factors have been shown to influence success rate as per previous study reports. The presence of periapical radiolucency affected the success rate, as a higher success rate was observed in teeth without periapical radiolucency as compared to those with periapical radiolucency. [93,4] The presence of periapical radiolucency is considered as an indication for retreatment.[94] An evaluation period of 1-2 years was sufficient to assess the success rate in teeth without periapical periodontitis, while in the presence of periapical lesions, a period of 2–5 years may be needed.[93] The presence or absence of coronal restoration providing complete coverage and seal also determines the success rate.[4]

An initial endodontic treatment is considered a failure when the tooth is associated with persisting periapical radiolucency of any size and this requires a surgical or nonsurgical retreatment. Early failures occur usually due to improper initial treatment, whereas reintroduction of microorganisms in the root canal system as in lack of coronal coverage is an important factor contributing to late failures.[4,95] A higher failure rate in elderly population as compared to young patients, was explained as being due to the widespread of periodontal diseases that cause bone loss and subsequent extraction of the tooth in older people.[93]

According to Imura, success rate in the primary and secondary endodontic therapy, and concluded that the primary endodontic treatment had a higher success rate of 94.0%, while for nonsurgical retreatment, it was 87.9% which was comparatively less.[4] The lower success rate of secondary treatment

is due to the incomplete elimination of certain microorganisms, which are resistant to disinfectants used during the treatment or due to the incomplete removal of filling material in the canal which form obstructions for various disinfectants to reach till the apical third for its complete action.[96,97] The persistence of microorganisms around the retained filling material, which act as the nidus for microbial growth, in the retreated tooth may be the cause of lesser success rate in nonsurgical retreatment cases. Various factors affect the endodontic retreatment outcome – like patient age, type of teeth retreated, presence of alterations in the normal course of root canal by procedural errors, the ability of the coronal restoration to be removable for accessing the pulp chamber, the methods of removal of existing filling materials, the ability to repair the pathologic or iatrogenic defects.[98]

In nonsurgical retreatment, the success was generally noticed to be lower (56-84%) than that of primary treatment (83-100%).[3,99,100] The presence of apical periodontitis is a cause of this low success rate. [99,101]. The outcome of retreatment was comparatively higher in teeth with sufficient filling, than in the teeth with apical periodontitis with insufficient root filling prior to retreatment.[102] With retreatment, the insufficiently filled root canals, which were the source of infection leading to the failure of root canal treatment, was adequately disinfected and obturated, facilitating favorable healing.[102] The cause of persistent radiolucency in the tooth with sufficient previous filling could be extra radicular infection, a true cyst, or presence of foreign body reaction which would not respond to orthograde retreatment.[99,102,103]

A large number of retreatment cases are being reported to our clinics nowadays. Root canal treatment failures occur when the treatment falls short of the acceptable standards. It is usually associated with procedural errors in infected tooth. It may be due to intra-radicular or extra-radicular infections or due to overfilling of root canals or inadequate coronal seal.[104] Success rate can be increased by adequately addressing the canals prior to surgical intervention which require complete removal of the previous filling, facilitating the debridement of residual necrotic tissues and eliminating the bacteria responsible for persistent periapical inflammation and filling of the root canal space.[103] Such cases require retreatment, in which the previous obturating materials has to be retrieved from the root canals. It is a consensus that removal of all the filling material in the retreatment procedures, provides adequate disinfection of the root canal system and favours conditions for new filling. The main goal of orthograde retreatment is to regain access to the apical foramen by the removal of root canal filling material, facilitating the complete cleaning and shaping with adequate debridement of the root canal system for achieving a complete obturation of the root canal space.[24]

Various materials have been used for root canal obturation from the past; of which Gutta percha is the universally accepted obturation material for the past 140 years, since it's introduction by Bowman in 1867.[15] It's a trans isomer of polyisoprene (rubber) and exists in two crystalline forms (α and β) - 60% crystalline form. The cis isomer is natural rubber – has amorphous form. [99,100] Gutta percha does not as such bond to sealer or canal walls and does not

have the inherent ability to seal canals, except perhaps by a physical one with the flow into lateral canals by warm compaction techniques.[15] Gutta-percha cones are available in conventional and standardized sizes 2%, 4% and 6%, greater taper cones - 4%, 6%, 8%, 10%, 12%, variable taper GP –Protaper – F1, F2. F3, Accessory GP cones - Extra fine, Fine-fine, Fine, Medium fine, fine medium, Medium, Large, Extra-large etc. Lack of adhesive property, inability to strengthen the tooth after obturation, lack of rigidity, shrinkage on cooling and its hydrophobic nature led to the development of newer obturation materials. [90,107,108]

Various sealers have been used along with gutta-percha to provide a complete seal of the root canal space, as gutta-percha does not have any inherent adhesive property to the canal walls, which would cause microleakage and the failure of endodontic therapy which follows. So, in order to overcome this drawback of gutta-percha, sealers have been developed. Sealers also fill the voids and irregularities in root canal, lateral and accessory canals, space between GP points in lateral condensation, also serve as lubricant for easy placement of the obturation cone till working length.[91]

In this study gutta-percha was used along with an epoxy resin based sealer, AH Plus, to achieve bonding to the canal walls which will give a fairer comparison with the other obturation materials which have adhesive properties for itself and its sealers, as these epoxy resin based sealer pose a comparatively increased difficulty in removal than the traditionally used zinc oxide based sealers without adhesive property.[105]

AH Plus sealer is a thermoplastic, two-component paste, epoxy resin based root canal sealer, that contains adamantine based on epoxy-amine resin, which permits removal of the material when required, is used along with Gutta-percha for bonding to the canal walls.[9,10,11] Epoxide paste consist of Di-epoxide, Calcium tungstate, Zirconium oxide, Aerosil, Pigment and the amine paste consists of 1-adamantane amine, N,N'-dibenzyl-5-oxa-nonandiamine-1,9, TCD-Diamine, Calcium tungstate, Zirconium oxide, Aerosil, Silicone oil.[27] In addition to the di-epoxide, the epoxide paste contains radio opaque fillers and Aerosil. The amine paste consists of three different types of amines, radio opaque fillers and Aerosil. AH Plus is characterized by very good mechanical properties, high radio opacity, little polymerization shrinkage, low solubility and a high degree of stability on storage.[27]

The second material used in this study was Resilon™. It is a new, synthetic resin-based polycaprolactone polymer which has been developed as a gutta-percha substitute to be used with Ephiphany™, RealSeal™, RealSeal SE™ (resin sealers) in an attempt to form an adhesive bond at the interface of the synthetic polymer-based core material, the canal wall and the sealer with Monoblock Effect.[13,14] Resilon bonds to dentinal walls when used in conjunction with its root canal sealer, Real Seal SE and forms a 'monoblock' within the canal.[14] This prevents the chances of microleakage between core material – sealer interface and the sealer - dentin interface.[15] Resilon cones come in a range of sizes similar to gutta-percha cones like ISO sized points and

pellets (Obtura III),0.02, 0.04, 0.06 tapers, accessory cones – extra fine to large.

The Resilon sealer is a dual-curable dental-resin composite sealer which has a total filler content of about 70% of its weight, allowing its easy removal in retreatment cases. The resin matrix constitutes of - Bis-GMA, ethoxylated Bis-GMA, UDMA, and hydrophilic difunctional methacrylates; and the fillers are - calcium hydroxide, barium sulphate, bioactive glass, bismuth oxychloride and silica – which is 70 percent by weight. The fillers include calcium hydroxide, bariumsulfate, barium glass and silica. It can bond to both the root dentin and Resilon cones. The Resilon bonding agent is a self-etching primer that contains sulfonic-acid terminated functional monomer, HEMA, water and a polymerization initiator.[16] Real seal SE is a self-etch dual-cure, hydrophilic resin sealer that bonds to both Resilon and dentin, which does not require a separate priming step. Obturation of root canals with this resin based material increased the resistance of tooth to vertical fracture. They also showed minimal leakage due to complete seal formation with adhesive bonding to root canals.[66] Its disadvantage is that it has polymerisation shrinkage and susceptibility to biodegradation. [84,104]

The third material used in this study is C point, which is a newer obturating water expandable material, having a 2 component design, with a central core of - Trogamid T and Trogamid CX - to provide good handling characteristics and a hydrophilic polymer coating, which is a cross linked copolymer of acrylonitrile and venyl pyrollidone - polymerized and cross

linked using allyl methacrylate - which radially expands and pushes the sealer into the lateral portals of root canal to seal the canal and makes it virtually impermeable to bacterial microleakage.[17,18]

Endosequence BC sealer is used along with CPoints in this study, as the bioceramic particles in the sealer can bond to the outer layer of CPoints as well as to the canal wall dentin with the formation of hydroxyapatite and water as byproduct. The nanoparticle size and hydroxyapatite producing formula allow it to flow readily into the dentinal tubes and form a true chemical bond. Unlike traditional base/catalyst hydrophobic sealers, EndoSequence BC Sealer utilizes the moisture naturally present in the dentinal tubules to initiate and complete its setting reaction. The patented biocompatible formula allows for absolutely zero shrinkage, gap-free seal.[108] This byproduct water can be utilized by the CPoints, due to its hydrophilic property, to expand in the root canal space to allow the sealer to flow into the lateral canals and dentinal tubules. This helps in achieving a good seal of the obturated root canal space.[87]

Various methods have been used to remove gutta-percha from root canal which includes the use of K type or H type files along with solvents like chloroform, xylene, eucalyptol, halothane or orange solvents, Gates-glidden drills, heated pluggers for coronal third material removal followed by hand instrumentation or ultrasonic technique. Flexible rotary instruments in low speed hand pieces can also be used for the removal of obturation material from the root canals. In this study the obturation material in the root canal is removed with the help of rotary retreatment Ni-Ti file systems which is less

time consuming and more efficient than hand instrumentation.[26,27,] The conventional use of hand instruments for removal of obturation material required more time and was tedious whereas rotary systems were faster in removing the material from root canal system. Rotary retreatment file system plasticizes obturation materials by the heat produced by friction on rotation and the specific flute design tends to pull the gutta-percha in to the file flute making the removal of obturation material more efficient.[20,39,40,65,71,86] But in some studies gutta-percha showed increased retrievability by hand instrumentation when compared to other obturation materials.[41]

In this study two rotary retreatment systems were used, Protaper retreatment file system and Mtwo retreatment file system.

Protaper Retreatment file system(D1, D2, D3) was developed to overcome the drawback of Protaper rotary finishing files which when used for obturation material removal from canals were unable to penetrate Gutta-percha and had higher incidence of fracture of 22.7% according to studies conducted by Betti and Ruddle.[109,110] Protaper retreatment files have triangular cross section along with three progressive tapers and length enabling the file to cut not only gutta-percha but also superficial layer of dentin during obturation material removal. D1 (size 30, 0.09 taper, 16mm length) was used for initial penetration and removal of coronal third of filling material, D2 (size 25, 0.08 taper, 18mm length) for middle third of root canal and D3 (size 20, 0.07 taper, 22mm length) to reach the working length. [20,110]

Mtwo retreatment files consists of two files R1(size 15, 0.05 taper), R2 (size 25, 0.05 taper) They have active tip with an increased tendency to reach the working length leaving more remaining material in the canal in single length preparation and it does not require crown down preparation as with other rotary systems. The characteristic design feature with a cutting tip and a constant helical angle, ensure the instrument's easy progression into the gutta-percha filling, without the need to exert pressure. [85,111]

Various methods have been used to assess efficiency of retreatment by identifying and measuring the remaining filling material in the root canal. Radiography and digitised images were used in the studies.[9,31,32,34] These methods provide two-dimensional image of three dimensional structures. Various other techniques like splitting of the teeth longitudinally and visualization with the help of stereomicroscopy or using digital camera and image analyser software as in other studies.[20,28,34,39] It can also be evaluated by making the teeth transparent by decalcification.[32,42] MicroCT has also been used in studies by Barletta *et al.* in 2007,[44] Hammad *et al.* in 2008[41]. It allows three-dimensional evaluation of the root canal system. CBCT allows the reproduction of the 3D information, has very less radiation exposure, is a non-invasive method without the requirement of destruction of the tooth sample.

The three different materials in this study shows three different sealing efficiency which affects the retrievability of the material from root canal. Hence the retrievability of each obturating material from the canal walls were evaluated by measuring the percentage volume of residual root canal obturating

material of the total volume of root canal after the obturating material is removed by two retrieval systems.

The sample size used in this study is based on an average sample size of previous studies. In a study done by Jayasenthil *et al.*[65] comparing the removability of gutta-percha obturated with two root canal sealers by Manual and Two-Rotary Ni-Ti Retreatment Systems, the no. of teeth used were in each group were 10. Using the prevalence of the previous study the sample size is calculated.[33]

In this study 60 freshly extracted single rooted mandibular premolars have been used so that canal preparation can be standardized and minimized to single canals and for achieving uniformity in the root canal morphology. The teeth were cleaned and stored in saline till usage (was used within three months of extraction). All the samples were radiographed in a bucco-lingual direction to rule out the presence of dentin pins, internal resorption, localized or diffuse calcifications, with fully formed apices and similar lengths and diameters. The teeth were decoronated at the cervical level near cemento-enamel junction, using high speed diamonds discs and the working length was adjusted in such a way that it is 15mm by inserting a size 10 K-file (Dentsply Maillefer), which was passively introduced into the canal until the tip was seen to exit at the major foramen so that the length is not a variable according to So *et al.* in 2008[45], Marfisi *et al.* in 2010[9], Luiz *et al.* in 2011[8]

All the root canals were biomechanically prepared in a crown down manner with Protaper universal rotary files; Sx, S1, S2, F1 and F2 till working length.[44] The finishing file features a decreasing rate of taper that enhances flexibility, reduces the possibility of over-preparing the coronal 2/3 of a canal and reduces the potential for taper lock[66] The apical patency was kept using #10 K file in between each rotary files and intermittent irrigation with 5.25% sodium hypochlorite and 17% ethylene diamine tetra acetic acid for smear layer removal and final rinse with saline.[89] Each instrument was used for 5 canals and discarded to avoid the chances of file fracture and procedural errors.

After adequate drying the canals with paper points, they were obturated with Gutta-percha and AH Plus sealer[89] in group 1 and II, Resilon and Realseal SE[16] in Groups III and IV using lateral condensation technique for achieving a uniform obturation without much voids. The obturation was considered to be complete when no spreader could enter more than 3mm into the obturation material.[16] The canals were obturated by lateral condensation as in other studies conducted by de Oliveira *et al.* in 2006[29], Schirrmeister *et al.* in 2006[30], Cunha *et al.* in 2007[34], Gu *et al.* in 2008[20] and Tasdemir *et al.* in 2008.[42,43] The self-etch real seal SE sealer in applied using master cone till working length after which the master cone coated with sealer was inserted till working length followed by lateral condensation with accessory cones.[16] Since Resilon, the resin based obturation system is a dual cure system, light curing was also done to achieve complete curing of the sealer for 40 seconds.[16] The Group V and VI were obturated with CPoints and Endosequence bioceramic sealer in single

cone obturation technique as a single cone can expand in the canal space in the presence of moisture in the canals and the sealer, to achieve a complete seal of the canal space.[90]

The obturated teeth were sealed with a temporary restorative material and stored in saline at 37ºC for 15 days to allow complete setting of the sealer.[8,32]

The volume of obturation material in the canal pre-removal and post-removal using the Protaper retreatment file systems in Group I, III and IV and with Mtwo retreatment system in Groups II, IV and VI were done was assessed with cone beam computed tomography as in the studies by Patel *et al.* 2009[121,113], Marfisi K *et al.* 2010[9].

The data obtained from the CBCT analysis were statistically analysed by Statistical Package for Social Sciences (SPSS 16.0) version. ANOVA (Post hoc test) followed by Dunnet t test applied to find statistical significant between the groups. Paired 't' test applied to find statistical significant before and after treatment. P value less than 0.05 considered statically significant at 95% confidence interval.

The analysis of the results from CBCT evaluation of remaining material volume percentage shows reduction in the mean volume percentage of material in all groups after removal using the corresponding retreatment file system as, 35.02 ± 1.19 to 6.92 ± 0.88 mm^3 in group I , 38.08 ± 1.45 to 7.99 ± 0.95 mm^3 in group II , 35.81 ± 0.98mm^3 to 5.81 ± 0.98mm^3 in group III , from 38.78 ±

1.17mm^3 to 7.51 ± 1.09mm^3 in group IV, from 39.99 ± 0.73mm3 to 9.95 ± 1.01mm^3 in group IV and from 37.09±1.28mm^3 to 11.00±0.90mm^3 in group IV. The retreatment system was efficient in removal of all the obturation materials from their respective groups.

The analysis of results showed a maximum volume percentage of remaining material in group VI (29.67±2.34%) and a minimum in group III (16.35±2.69%) and group I and II showed a mean volume percentage of 19.71±1.98% and 21.00±2.41% respectively, showing that the Resilon obturation was found to be the most easily retrievable material among the three experimental materials and CPoint point to be the most difficult to be retrieved from the canals and gutta-percha was comparatively better than CPoints but not than Resilon.

From these results, we can infer that the retreatment systems are efficient in material retrievability for retreatment purpose. This result is in accordance with other study results by Giuliani *et al.* in 2008[39], Somma *et al.* in 2008[40], Gu LS *et al.* in 2008[20], where rotary instrumentation was effective in achieving reduction in the material in canals even though completely clean canals could not be achieved. Hammad *et al.* in 2008[41] had compared the efficacy of hand instrumentation in retrievability of different obturation materials and noticed achievement of cleaner canals with hand instrumentation. Wasnik *et al.* in 2013[70] proved that use of rotary as well as hand instrumentation could not achieve a completely cleaner canal. Ramzi *et al.* in 2010[50] showed that Mtwo file system alone and along with Mtwo retreatment

file system showed comparatively similar cleaning efficiency with or without the presence of solvents whereas Dhillon JS *et al.* in 2014[74], proved that Protaper Universal rotary system alone and along with Protaper retreatment system showed similar efficacy in the retrievability of gutta-percha. Singh *et al*. in 2015[85] proved Mtwo retreatment file system to be better than hand instrumentation where as in contrary to his result Jayasenthil A *et al.* in 2012[65] and Jaiswal *et al.* in 2015[86], proved hand instrumentation to be better than rotary instrumentation.

From the results, we can infer that group VI (29.67±2.34 %) had the highest mean volume percentage of remaining filling material than all the other groups showing the least retrievability of CPoint with Protaper retreatment system.

CPoint showed the highest volume percentage of residual filling material in all the experimental materials. This can be due to the hydrophilic property of CPoint to expand laterally in the canal system utilizing the moisture from the canal as well as the sealer. This expansion pushes the associated bioceramic sealer to be pushed into the lateral canals and dentinal tubules increasing the physical adhesion of the material.[16,17,62,63] Moreover, the Endosequence bioceramic sealer forms chemical bond with the root canals by the production of hydroxyapatite and water, and the nanoparticle size of the bioceramic particles allows to deeper penetration of sealer in to the canal irregularities and dentinal tubules, facilitating the increased bond of CPoints to the root canals.[84,108] The water produced as by-product is utilized by the CPoint

to expand laterally in the canals.[108] The polymer technology of CPoint is, manipulated in a such a manner by the manufacturers, that the obturation point shows controlled expansion by only lateral expansion rather than axial direction which helps in swelling up of the material only laterally.[16,17,62,73,83,87,90] The anisotropic expansion of the material stops once resistance is felt, thus preventing the fracture of root that would be generated during lateral expansion.[16,17]

Group V (24.91±2.66) showed the next highest mean volume percentage of residual material which was higher than all the other groups except group VI (29.67±2.34 %).

This shows that CPoint removal was comparatively better with Protaper retreatment file system than Mtwo retreatment file system. This is in accordance to the studies conducted by Tasdemir *et al.* in 2008[42] and Khedmat *et al.* in 2016[89] which showed a higher efficacy of Protaper retreatment file systems. According to these authors,[42,89] this efficiency is considered to be due to the difference in design feature of both the file systems. Protaper retreatment file system has a specific flute design, which enables it to cut the superficial dentin along with the cutting of obturation material and the progressive taper, of D1, D2 and D3 files which makes the file to be able to shape specific areas of the canal with one file and the variable diameter, which allows defined cutting in specific sections without the instrument being stressed as there is no contact with other portions of the canal.

According to Schafer *et al.* in 2006[101] and Tasdemir *et al.* in 2008[43] increased amount of residual material in the canals of Mtwo retreatment group is attributed to its single length penetration with its high and fast cutting efficiency attained by its special design feature – S shaped cross section, increased pitch length in the apical coronal direction, positive rake angle with two cutting edges.

Dadresanafer *et al.* in 2011[67], found out in a study that Mtwo was more efficient than Protaper due to its small core diameter, great chip removal capacity and greater chip space providing the greater cutting efficiency. The surface treatment of these files provides greater wettability to achieve cleaner canals and the less cutting efficiency of Protaper was due to its convex triangular cross section of the D series files, which reduces the contact area with the canals. [67,103,114]

In studies by Mohebbi *et al.* 2012[63] and Alves *et al.* in 2014[75], they showed similar efficacy of both the retreatment file systems.

Group I (19.71±1.98%) and II (21.00±2.41%) showed lesser mean volume percentage of remaining filling material when compared to Group V and VI whereas was higher than Group III (16.35±2.69%) and IV (19.40±2.95%).

This showed the higher retreatment efficacy of gutta-percha in comparison to CPoint groups and lesser retreatment efficacy in comparison to Resilon groups.

Gutta-percha had left more residual filling material in the canal than Resilon groups. This could be due to the non-adhesive property of Gutta-percha and the adhesive property of AH Plus sealer which could bond with the dentinal wall but not with the obturation cone (Wilcox *et al* in 1987[1], Friedman *et al* in 1992). Hence the removal of Gutta percha with rotary left more of the sealer adhered to the canal walls making more residual material in the canals compared to the Resilon group. Gutta percha was comparatively easily retrievable as the rotary movement of files created friction in gutta-percha heating it up and softening the material, thus facilitating easy removal of Gutta percha.

This result is in accordance to studies done by de Olieviera *et al.* in 2006[29], Schirrmeister *et al.* in 2006[30], Ezzie *et al.* in 2006[28], Cunha *et al.* in 2007[34], Kumar AG *et al.* in 2009[10], Beshr *et al.* in 2015[82], and contradicts the result of the study by Hassanloo *et al.* in 2007[36], Tasdemir *et al* in 2008[42,43], Zarei M *et al.* in 2009[12]. In a study by Iriboz *et al.* in 2014[72] both Resilon and Gutta percha showed similar retrievability during retreatment.

The easy retrievability of Resilon could be attributed to its monoblock formation property in which the sealer can bond to both the obturation cone as well as the dentinal wall creating a single continuous obturation making the complete removal of material as a whole without leaving traces of sealer as seen with gutta-percha removal. It can also be attributed to the incomplete polymerisation of the resin sealer that may be due to the effect of residual Sodium hypochlorite, which is a strong oxidising agent creating an oxygen rich

layer on the canal walls which inhibits the free radical polymerisation resulting in reduced bond of the Resilon to root dentin, before which the removal would have been attempted and hence the easy retrievability substantiated.[57,58] The inability of sealer to completely coat the canal walls due to incomplete removal of smear layer interfering with the bonding can also be attributed to the easy retrievability of the Resilon obturation.[57] The high C-factor of the root canals during polymerization of resinous endodontic sealers may cause gaps along the dentin filling interface and the concurrent polymerization shrinkage with the reduction of volume of monomer produce stress in the material causing debonding from the root canal walls, reducing adaptation and further microleakage. These may be considered the factors for ease of retrievability of Resilon and resin based sealer in this study.[35,57,115]

The study being an *invitro* one, there is associated limitations as the study could not be conducted under oral environmental conditions, and to conclude on the results we need clinical trials. The associated risk of instrument fracture in the root canals during removal of obturation material and the possibility of apical extrusion of debris could also be not neglected. The chances of vertical fracture of the tooth due to the development and propagation of microcracks created during instrumentation also has to be considered.

The obturation material in the root canals of teeth which need retreatment, in case of primary endodontic treatment failure, which hinders the further canal debridement and disinfection, must be removed from the root

canals for providing an acceptable three dimensionally sealed obturation. Various factors affect the retrievability of these filling material. The retreatment methods with rotary systems also varies with its different design features. Hence various clinical trials have to be attempted with different materials and methods before concluding on the retrievability of any obturation material.

SUMMARY AND CONCLUSION

Endodontic retreatment has become necessary nowadays in practice due to various reasons which would have led to the failure of the primary endodontic treatment: which could be pathologic or iatrogenic. In those cases, which require retreatment, the removal of previous filling material is essential which may pose hindrance in disinfection and debridement of the canal for providing better treatment.

The removal ability of these materials depend upon their adhesiveness and bonding ability to the canal walls. The traditionally used Gutta-percha lacks the property of adhesion and hence have been used along with sealers which helps to fill in the voids and gaps in between the obturation cones and canal wall. Development of resin based obturation has overcome the drawback with gutta-percha as these resin-based obturation materials can form monoblock by bonding to the canal walls with the help of resin based sealer forming a continuous single unit. Development of CPoint, which shows hygroscopic expansion has facilitated the use of single cone obturation method, as these materials form a perfect seal after obturation due to the pushing of the accompanying sealer into the lateral canals and dentinal tubules. Various methods can be adopted for the removal of obturation materials from the canals, like hand and rotary retrieval methods, with or without the use of chemical solvents.

The present study was done to compare the removal ability of these three obturation material removed using two different rotary retreatment file systems.

Sixty single rooted mandibular premolars extracted for orthodontic purpose was used for this study. After decoronation and working length determination the biomechanical preparation of the root canals was done using Protaper Universal rotary system till F2 shaping file size. The specimens were randomly divided into six groups with ten samples each. Group I and Group II were obturated using Gutta-percha and AH Plus sealer, Group III and IV with RealSeal Resilon points and RealSeal SE sealer and the Group V and VI with CPoint and Endosequence BC sealer. The CBCT volume analysis of filling material in the canals were evaluated (in mm^3). Retreatment was done with Protaper Universal retreatment system in Group I, III and V and with Mtwo Retreatment file system in Group II, IV and VI. Again, the CBCT volume analysis of remaining filling material in the canal was calculated and compared. The remaining volume percentage was calculated to compare the retrievability of the materials. The values obtained were statistically analyzed by Statistical Package for Social Sciences(SPSS) version 16.0. the data were expressed in its mean and standard deviation. The analysis of results shows a maximum remaining volume percentage in Group VI (29.67±2.34%) and the least in Group III (16.35±2.69%). The results show that RealSeal is the easiest to be retreatable and CPoints the most difficult to be retreatable whereas gutta-percha

is comparatively better in retreatment efficacy than CPoints but inferior to RealSeal.

Hence within the limitations of this *invitro* study it may be concluded that the canals obturated with CPoints and Endosequence BC sealer are the least retreatable among the study groups which can be attributed to the hygroscopic expansion property of the obturation material, which on expansion in the presence of moisture in the canals and the accompanying sealer, pushes the sealer into the lateral canals and dentinal tubules. This sealer which has high penetration due to the Nano-size of the bio ceramic particles in the sealer can bond to the dentin by the formation of hydroxyapatite and the byproduct water is utilized by the obturation point for expansion. Formation of physical as well as chemical bond in this group makes its removal the most difficult one.

TABLES

Table-1: Mean volume before retreatment, after removal and percentage of total of different groups

Groups	Total		
	Before (MEAN±SD)	**After (MEAN±SD)**	**Percentage (%)(MEAN±SD)**
Group-I	35.02±1.19	6.92±0.88	19.71±1.98
Group-II	38.08±1.45	7.99±0.95	21.00±2.41
Group-III	35.81±0.98	5.81±0.98	16.35±2.69
Group-IV	38.78±1.17	7.51±1.09	19.40±2.95
Group-V	39.99±0.73	9.95±1.01	24.91±2.66
Group-VI	37.09±1.28	11.00±0.90	29.67±2.34

Table-2: Comparison of mean values before retreatment and after removal within the groups

Groups	Total		P value
	Before (MEAN±SD)	**After (MEAN±SD)**	
Group-I	35.02±1.19	6.92±0.88*	**0.001**
Group-II	38.08±1.45	7.99±0.95*	**0.001**
Group-III	35.81±0.98	5.81±0.98*	**0.001**
Group-IV	38.78±1.17	7.51±1.09*	**0.001**
Group-V	39.99±0.73	9.95±1.01*	**0.001**
Group-VI	37.09±1.28	11.00±0.90*	**0.001**

(*P<0.05 significant compared before with after within the groups)

Table-3: Comparison of mean values between Group-I and Group-II

Groups	Total		
	Before (MEAN±SD)	**After (MEAN±SD)**	**Percentage (%)(MEAN±SD)**
Group-I	35.02±1.19	6.92±0.88	19.71±1.98
Group-II	38.08±1.45	7.99±0.95	21.00±2.41
P value	**1.45**	**0.87**	**0.6**

(P>0.05 no significant difference compared Group-I with Group-II)

Table-4: Comparison of mean values between Group-III and Group-IV

Groups	Total		
	Before (MEAN±SD)	**After (MEAN±SD)**	**Percentage (%)(MEAN±SD)**
Group-III	35.81±0.98	5.81±0.98	16.35±2.69
Group-IV	38.78±1.17	7.51±1.09	19.40±2.95
P value	**1.23**	**0.67**	**0.54**

(P>0.05 no significant difference compared Group-III with Group-IV)

Table-5: Comparison of mean values between Group-V and Group-VI

Groups	Total		
	Before (MEAN±SD)	**After (MEAN±SD)**	**Percentage (%)(MEAN±SD)**
Group-V	39.99±0.73	9.95±1.01	24.91±2.66
Group-VI	37.09±1.28	11.00±0.90	29.67±2.34
P value	**1.45**	**0.92**	**0.63**

(P>0.05 no significant difference compared Group-V with Group-VI)

Table-6: Comparison of mean values Group-I with other groups

Groups	Total		P value
	Before (MEAN±SD)	**After (MEAN±SD)**	
Group-I	35.02±1.19	6.92±0.88	
Group-II	38.08±1.45	7.99±0.95	**0.87**
Group-III	35.81±0.98	5.81±0.98*	**0.03**
Group-IV	38.78±1.17	7.51±1.09	**0.56**
Group-V	39.99±0.73	9.95±1.01*	**0.03**
Group-VI	37.09±1.28	11.00±0.90*	**0.03**

(*P<0.05 significant compared Group-I with other groups)

Table-7: Comparison of mean values Group-II with other groups

Groups	Total		P value
	Before (MEAN±SD)	After (MEAN±SD)	
Group-II	38.08±1.45	7.99±0.95	
Group-I	35.02±1.19	6.92±0.88	**0.87**
Group-III	35.81±0.98	5.81±0.98*	**0.03**
Group-IV	38.78±1.17	7.51±1.09	**0.47**
Group-V	39.99±0.73	9.95±1.01*	**0.03**
Group-VI	37.09±1.28	11.00±0.90*	**0.03**

(*P<0.05 significant compared Group-II with other groups)

Table-8: Comparison of mean values Group-III with other groups

Groups	Total		P value
	Before (MEAN±SD)	After (MEAN±SD)	
Group-III	35.81±0.98	5.81±0.98	
Group-I	35.02±1.19	6.92±0.88*	**0.03**
Group-II	38.08±1.45	7.99±0.95*	**0.03**
Group-IV	38.78±1.17	7.51±1.09	**0.67**
Group-V	39.99±0.73	9.95±1.01*	**0.03**
Group-VI	37.09±1.28	11.00±0.90*	**0.03**

(*P<0.05 significant compared Group-III with other groups)

Table-9: Comparison of mean values Group-IV with other groups

Groups	Total		P value
	Before (MEAN±SD)	After (MEAN±SD)	
Group-IV	38.78±1.17	7.51±1.09	
Group-I	35.02±1.19	6.92±0.88	**0.56**
Group-II	38.08±1.45	7.99±0.95	**0.47**
Group-III	35.81±0.98	5.81±0.98	**0.67**
Group-V	39.99±0.73	9.95±1.01*	**0.03**
Group-VI	37.09±1.28	11.00±0.90*	**0.03**

(*P<0.05 significant compared Group-IV with other groups)

Table-10: Comparison of mean values Group-V with other groups

Groups	Total		P value
	Before (MEAN±SD)	After (MEAN±SD)	
Group-V	39.99±0.73	9.95±1.01	
Group-I	35.02±1.19	6.92±0.88*	**0.03**
Group-II	38.08±1.45	7.99±0.95*	**0.03**
Group-III	35.81±0.98	5.81±0.98*	**0.03**
Group-IV	38.78±1.17	7.51±1.09*	**0.03**
Group-VI	37.09±1.28	11.00±0.90	**0.92**

(*P<0.05 significant compared Group-V with other groups)

Table-11: Comparison of mean values Group-VI with other groups

Groups	Total		P value
	Before (MEAN±SD)	After (MEAN±SD)	
Group-VI	37.09±1.28	11.00±0.90	
Group-I	35.02±1.19	6.92±0.88*	**0.03**
Group-II	38.08±1.45	7.99±0.95*	**0.03**
Group-III	35.81±0.98	5.81±0.98*	**0.03**
Group-IV	38.78±1.17	7.51±1.09*	**0.03**
Group-V	39.99±0.73	9.95±1.01	**0.92**

(*P<0.05 significant compared Group-VI with other groups)

Table-12: Multiple comparisons of mean values between the groups

Groups	Total	
	Before (MEAN±SD)	**After (MEAN±SD)**
Group-I	35.02±1.19	6.92±0.88
Group-II	38.08±1.45	7.99±0.95
Group-III	35.81±0.98	5.81±0.98*,#
Group-IV	38.78±1.17	7.51±1.09
Group-V	39.99±0.73	9.95±1.01*,#,$,Ⅱ
Group-VI	37.09±1.28	11.00±0.90*,#,$,Ⅱ

(*P<0.05 significant compared Group-I with other groups, #P<0.05 significant compared Group-II with other groups, $P<0.05 significant compared Group-III with other groups, ⅡP<0.05 significant compared Group-IV with other groups)

Table-13: Multiple comparisons of mean total percentage values between the groups

Groups	Total Percentage (%)(MEAN±SD)	Comparison	P value
Group-I	19.71±1.98	**I with III, V,VI**	**0.002**
Group-II	21.00±2.41	**II with III, V,VI**	**0.003**
Group-III	16.35±2.69*,#	**III with I, V, VI**	**0.001**
Group-IV	19.40±2.95	**IV with V, VI**	**0.02**
Group-V	24.91±2.66*,#,$,‖	**V with I, II, III, IV**	**0.002**
Group-VI	29.67±2.34*,#,$,‖	**VI with I, II, III, IV**	**0.003**

(*P<0.05 significant compared Group-I with other groups, #P<0.05 significant compared Group-II with other groups, $P<0.05 significant compared Group-III with other groups, ‖P<0.05 significant compared Group-IV with other groups)

FIGURES

Fig 1: Armamentarium

Fig 2: Sixty extracted single rooted mandibular premolar teeth

Fig 3: Decoronation

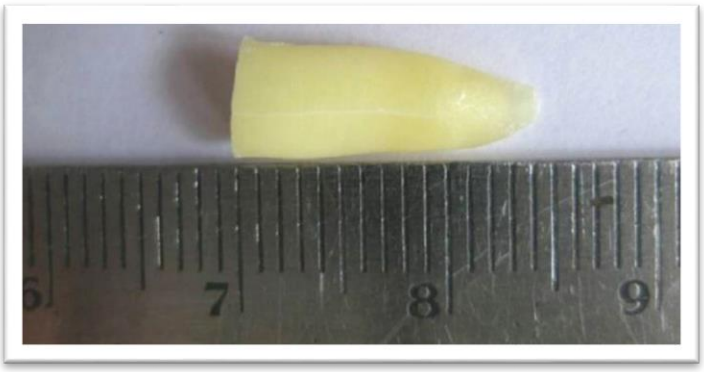

Fig 4: Working length determination

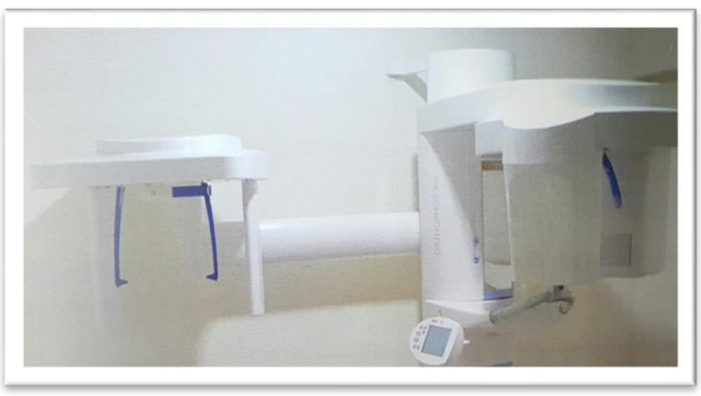

Fig 5: CBCT – CS9300 equipment (Carestream Healthcare India Pvt. Ltd)

TOOTH PREPARATION WITH PROTAPER ROTARY FILES

Fig 6 a: Tooth preparation with Sx Protaper file

Fig 6 b: Tooth preparation with S1 Protaper file

Fig 6 c: Tooth preparation with S2 Protaper file

Fig 6 d: Tooth preparation with F1 Protaper file

Fig 6 e: Tooth preparation with F2 Protaper file

OBTURATION OF GROUP I AND II

Fig 7 a : AH Plus Sealer dispensed on mixing pad

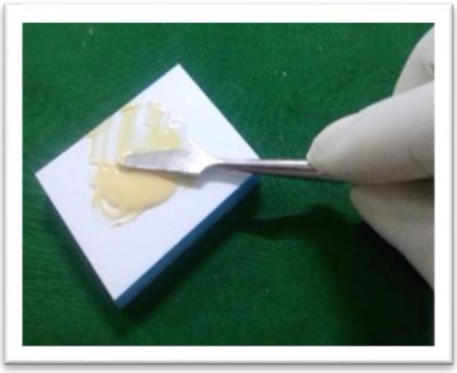

Fig 7 b : Sealer mixing

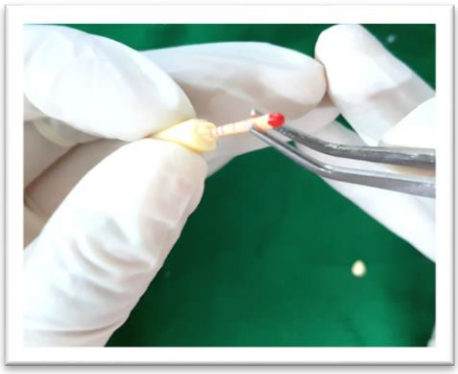

Fig 7 c: Guttapercha Master cone placement coated with sealer

Fig 7 d : Lateral condensation

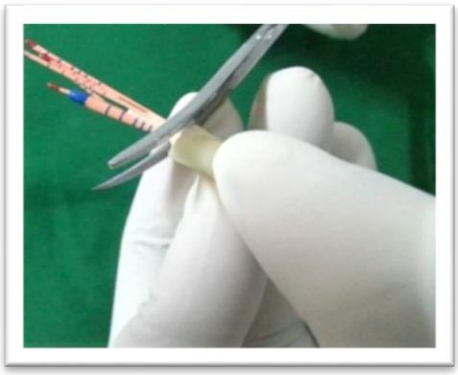

Fig 7 e : Completed obturation

OBTURATION OF GROUP III AND IV

Fig 8 a : Dispensed sealer – RealSeal SE

Fig 8 b: Resilon Master cone placement coated with sealer

Fig 8 c : Lateral condensation

Fig 8 d : Light curing of the sealer

Fig 8 e : Completed obturation

OBTURATION OF GROUP V AND VI

Fig 9 a : Dispensed sealer

Fig 9 b : F2 size- verifier and CPoint

Fig 9 c : Application of Endosequence BC sealer

Fig 9 d : Check for fit with verifier

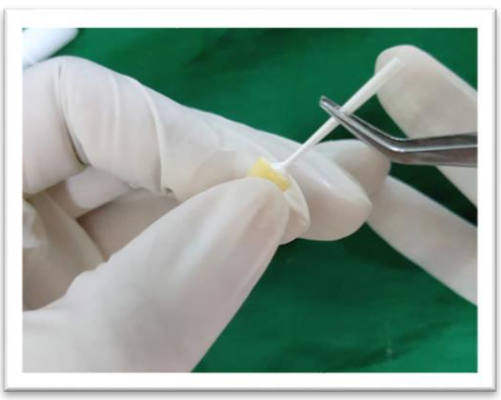

Fig 9 e : Single cone obturation with CPoint and Endosequence BC Sealer

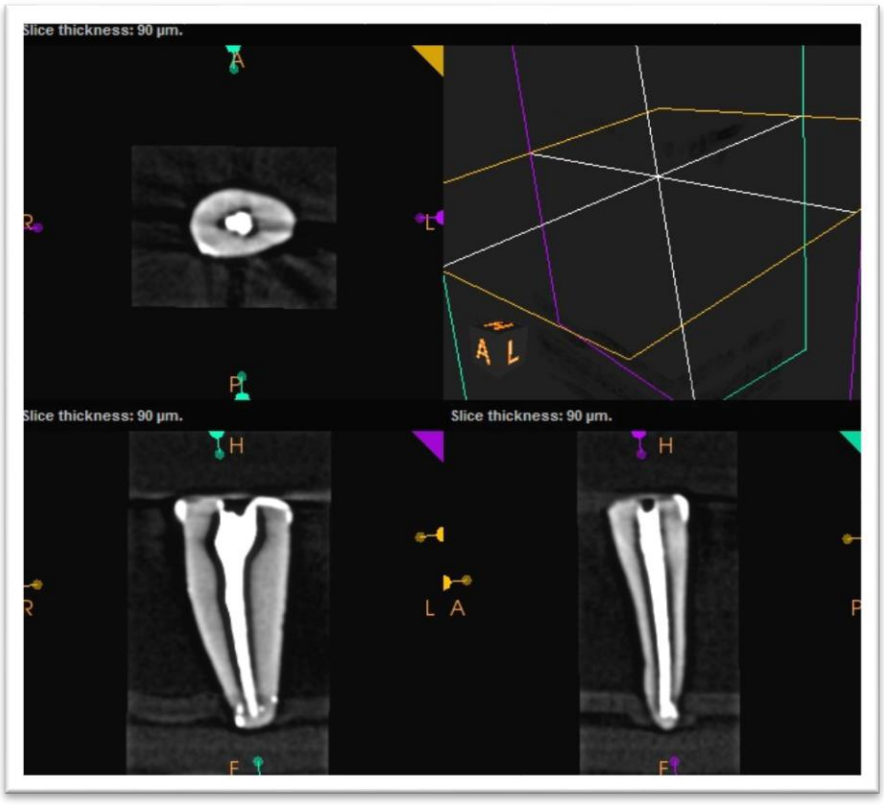

Fig 10 : CBCT image of group I before retreatment

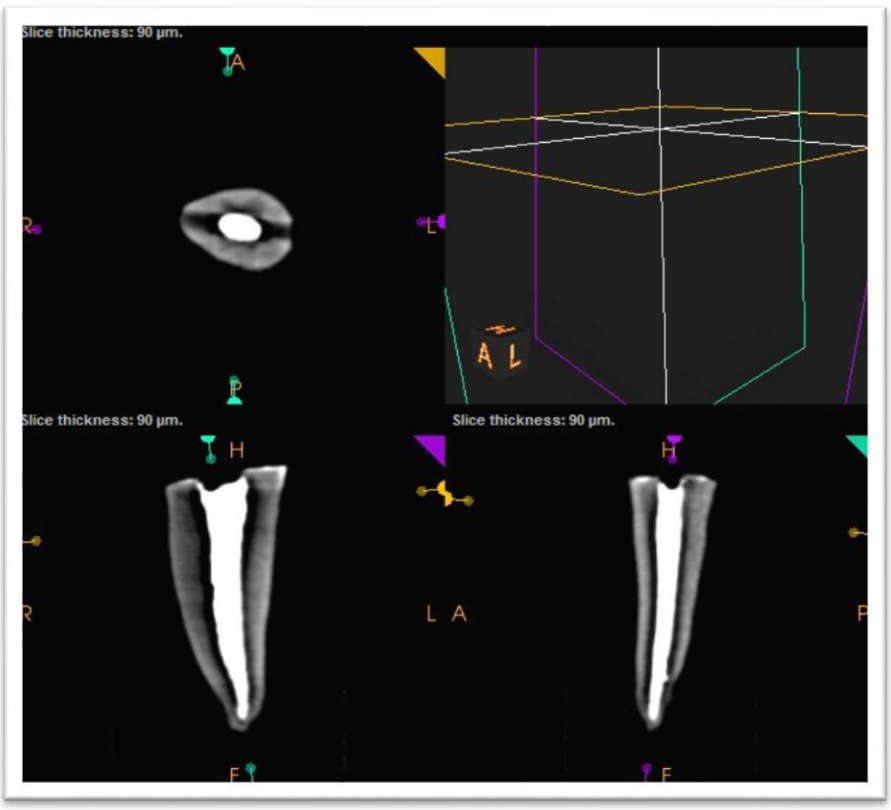

Fig 11 : CBCT image of group II before retreatment

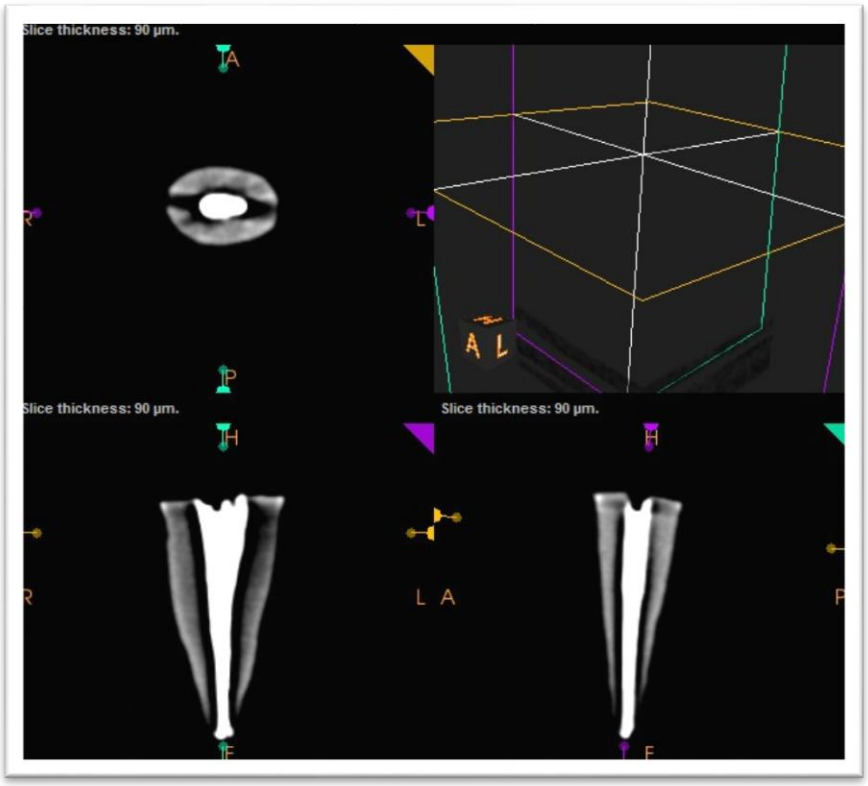

Fig 12 : CBCT image of group III before retreatment

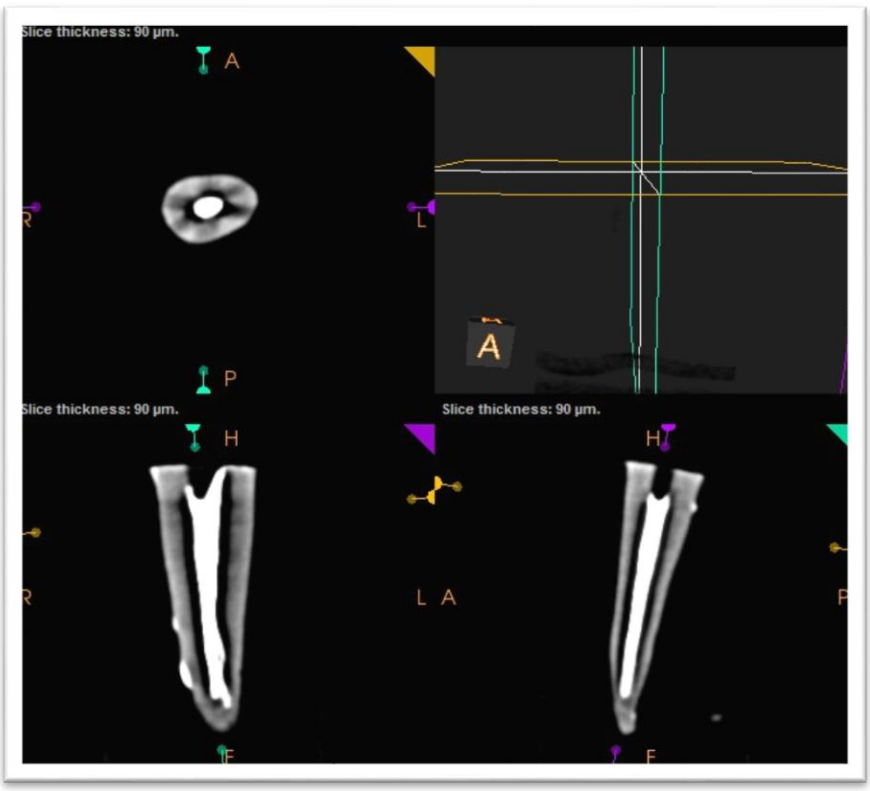

Fig 13 : CBCT image of group IV before retreatment

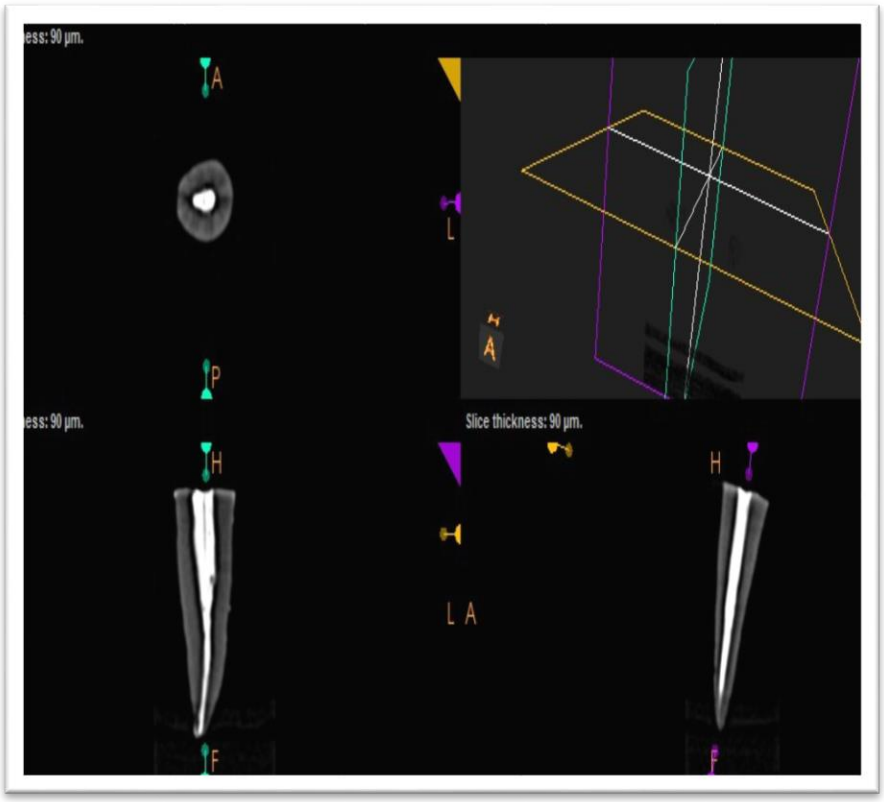

Fig 14 : CBCT image of group V before retreatment

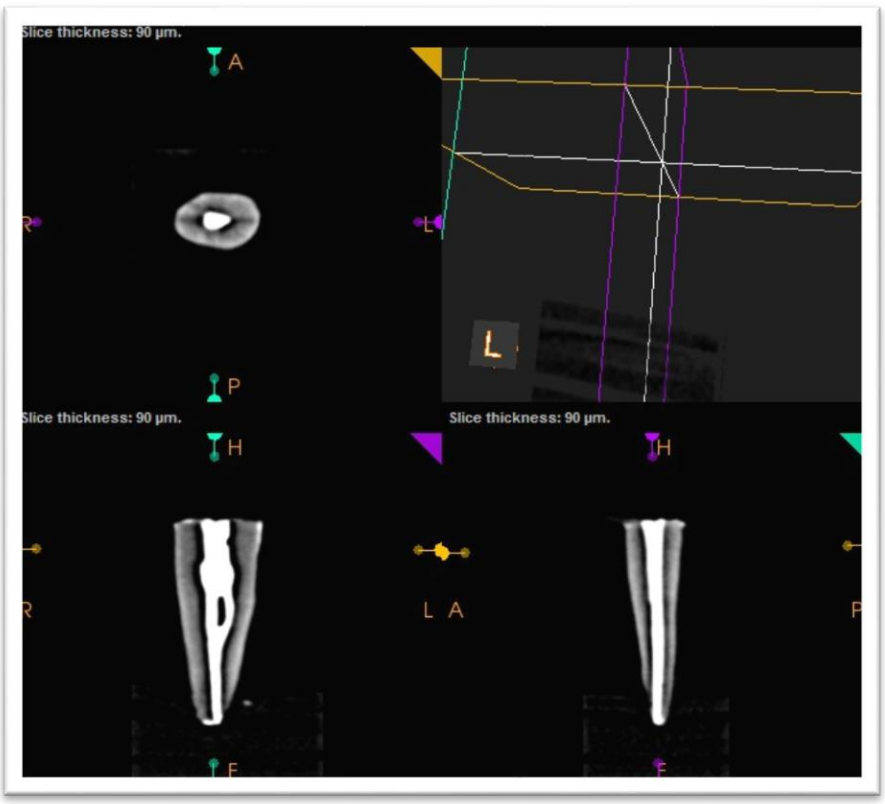

Fig 15 : CBCT image of group VI before retreatment

RETREATMENT OF GROUPS I, III, V

Fig 16 : Protaper retreatment files – D1, D2, D3

Fig 17 a, b, c : Retreatment of group I with Protaper retreatment files

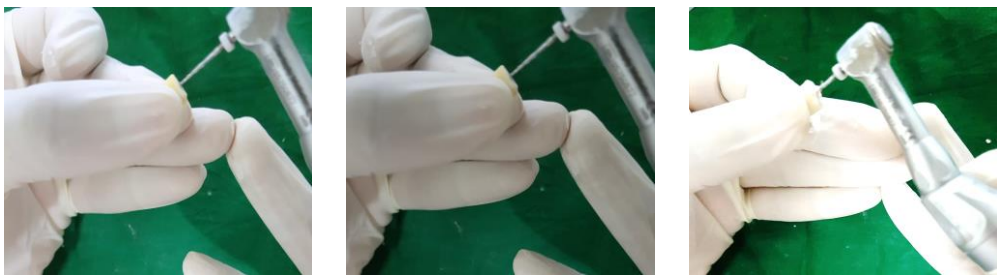

Fig 18 a, b, c : Retreatment of group III with Protaper retreatment files

Fig 19 a, b, c : Retreatment of group IV with Protaper retreatment files

RETREATMENT OF GROUPS II, IV, VI

Fig 20 : Mtwo retreatment files – R1 and R2

Fig 21 a,b : Retreatment of group II with Mtwo retreatment files

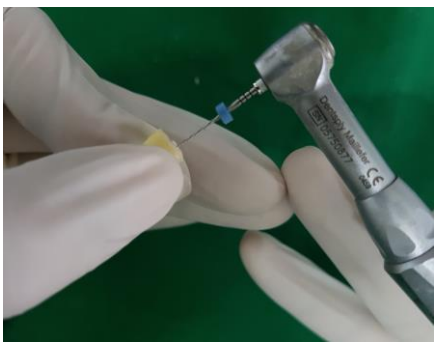

Fig 22a,b : Retreatment of group IV with Mtwo retreatment files

Fig 23 a,b : Retreatment of group VI with Mtwo retreatment files

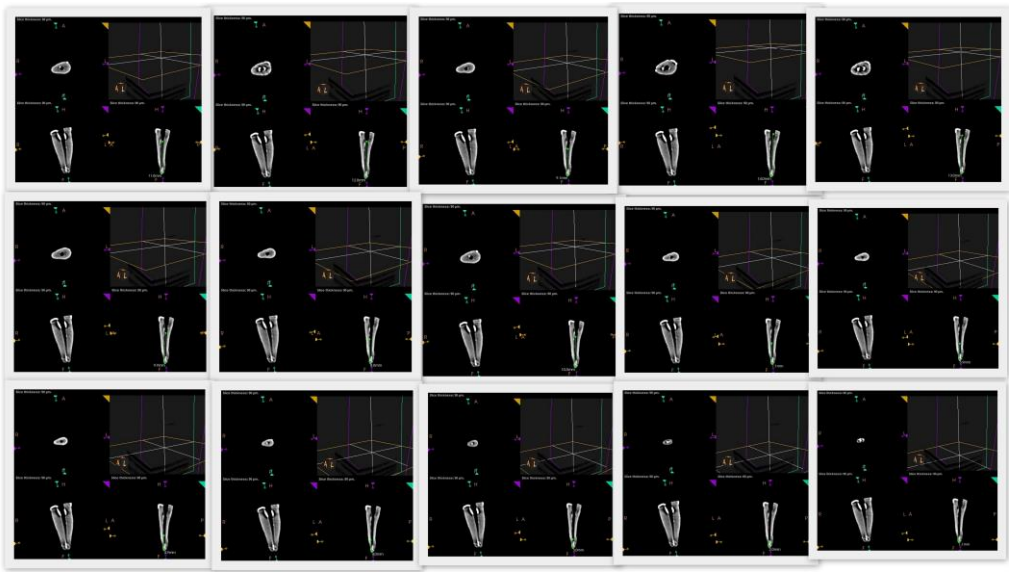

Fig 24 : CBCT images of group I after removal

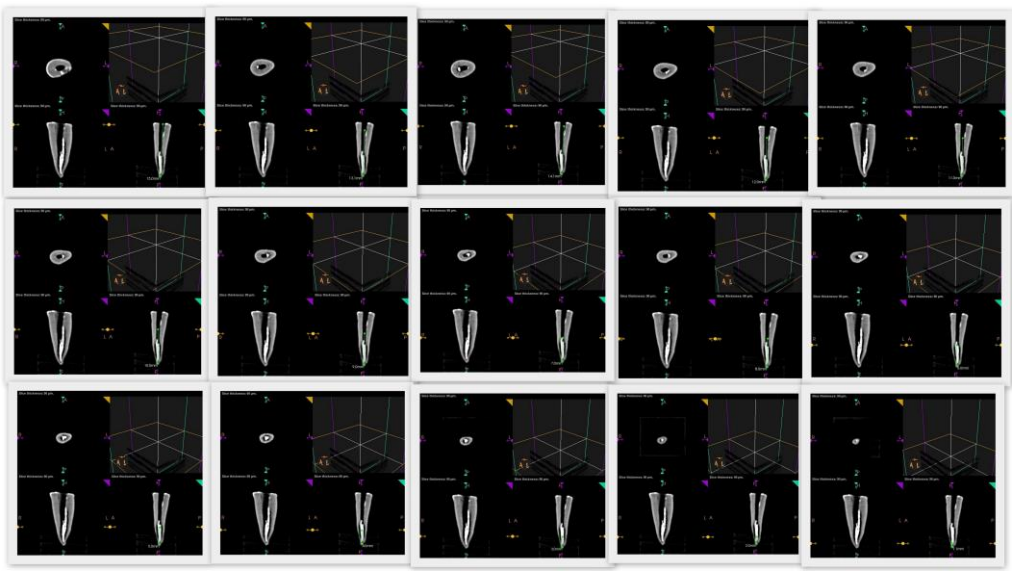

Fig 25 : CBCT images of group II after removal

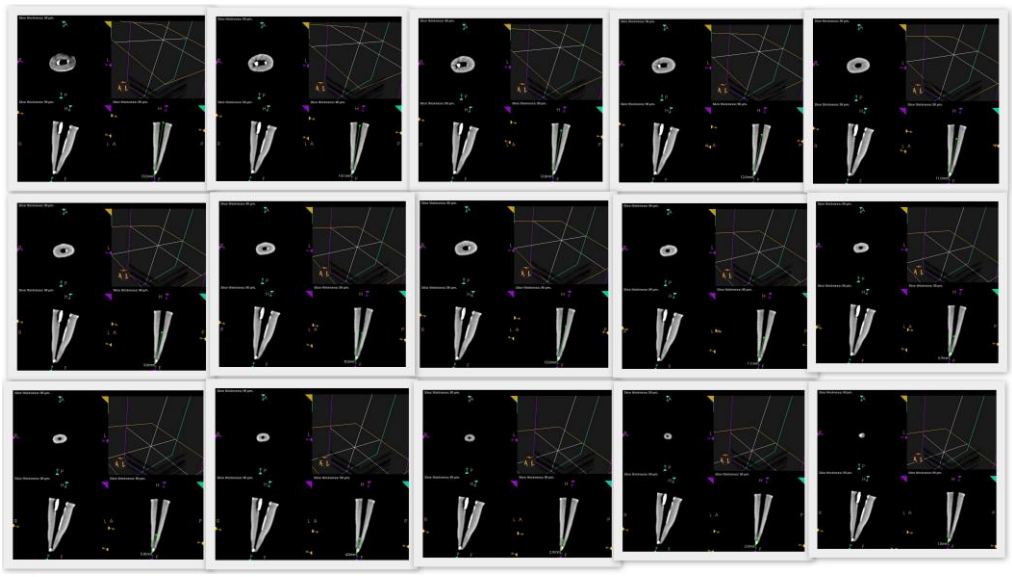

Fig 26 : CBCT images of group III after removal

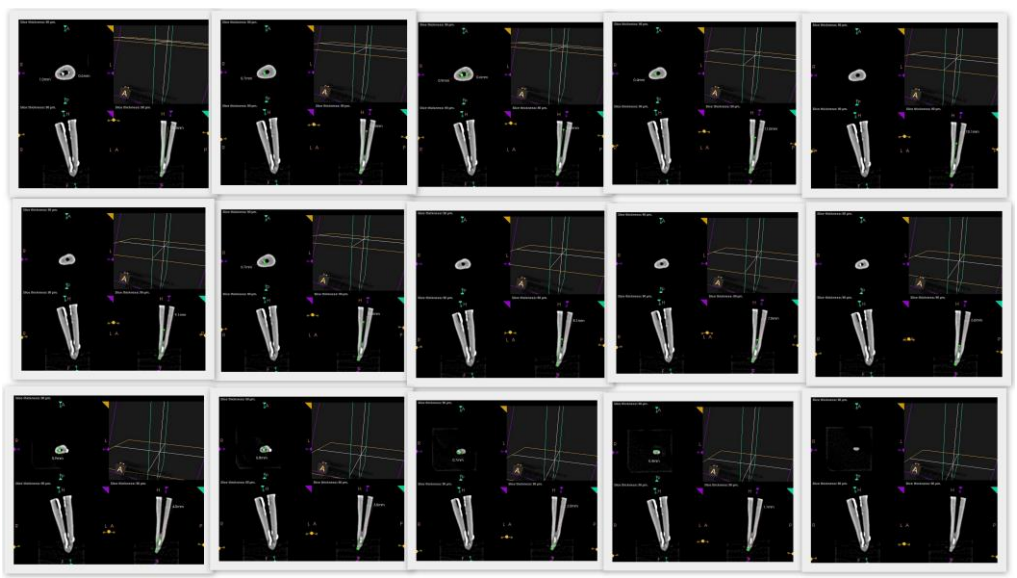

Fig 27 : CBCT images of group IV after removal

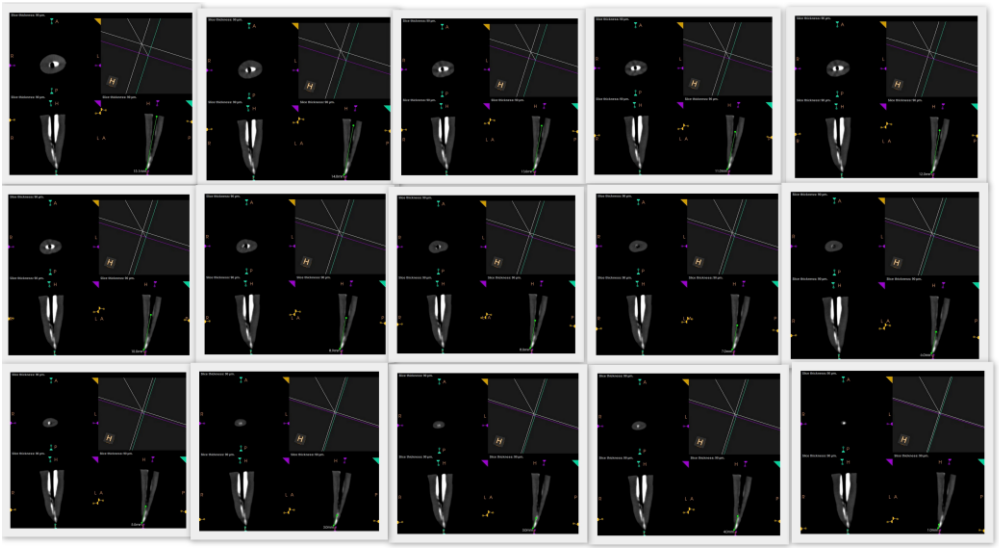

Fig 28 : CBCT images of group V after removal

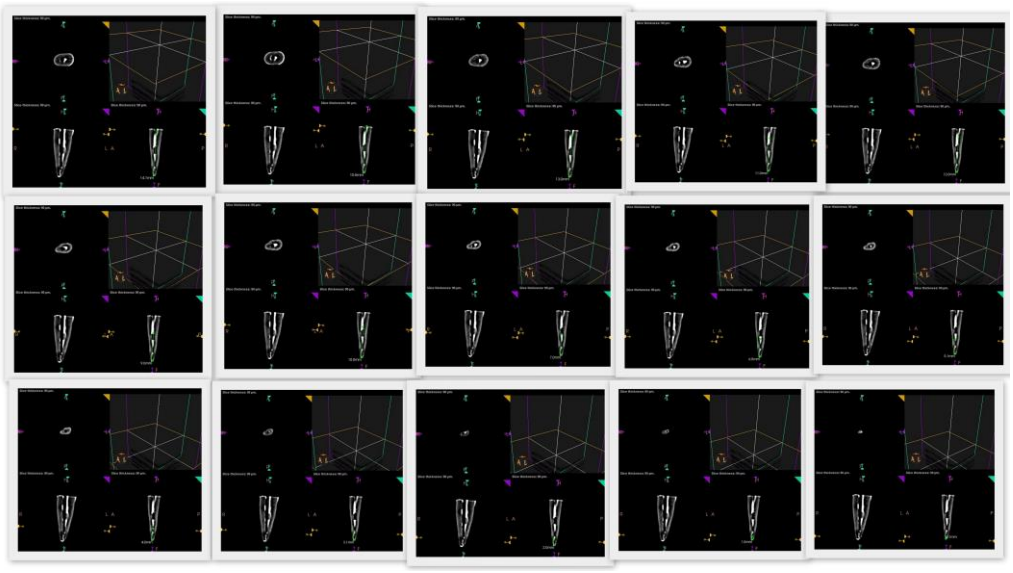

Fig 29 : CBCT images of group VI after removal

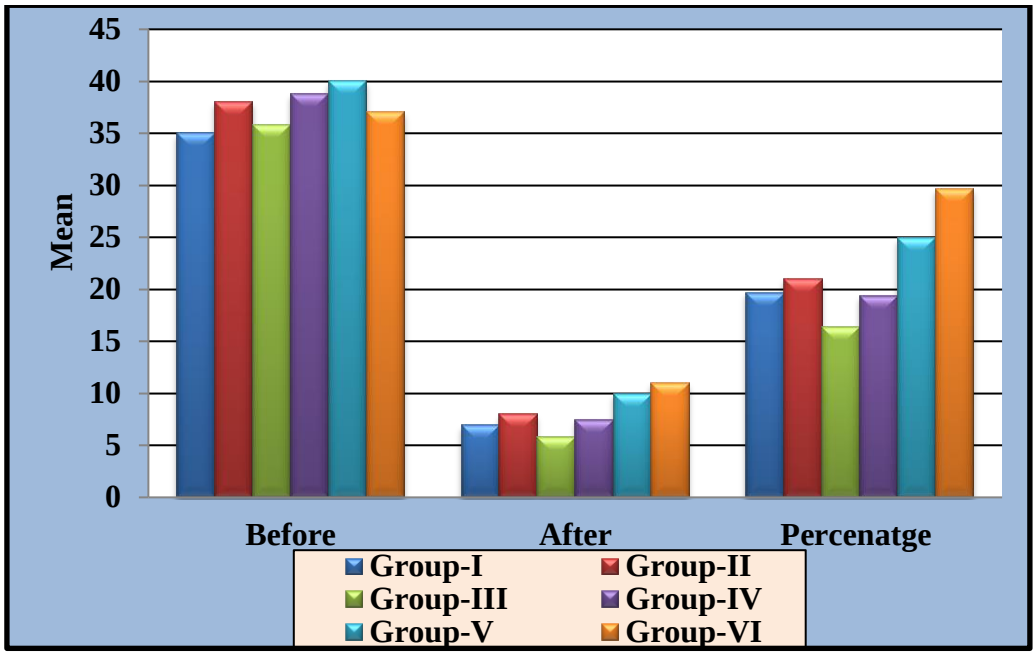

Fig 30: Graphical representation of Mean before retreatment, after removal and percentage of total of different groups

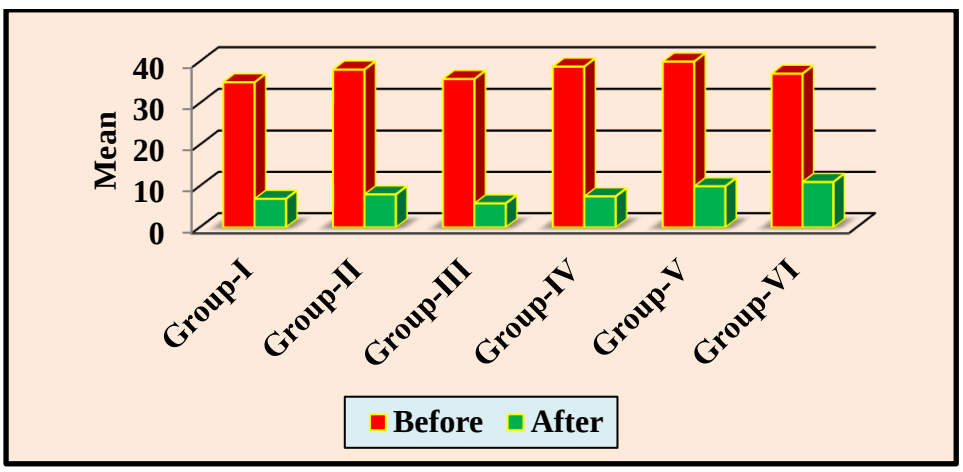

Fig 31 : Graphical representation of Comparison of mean values before retreatment and after removal within the groups

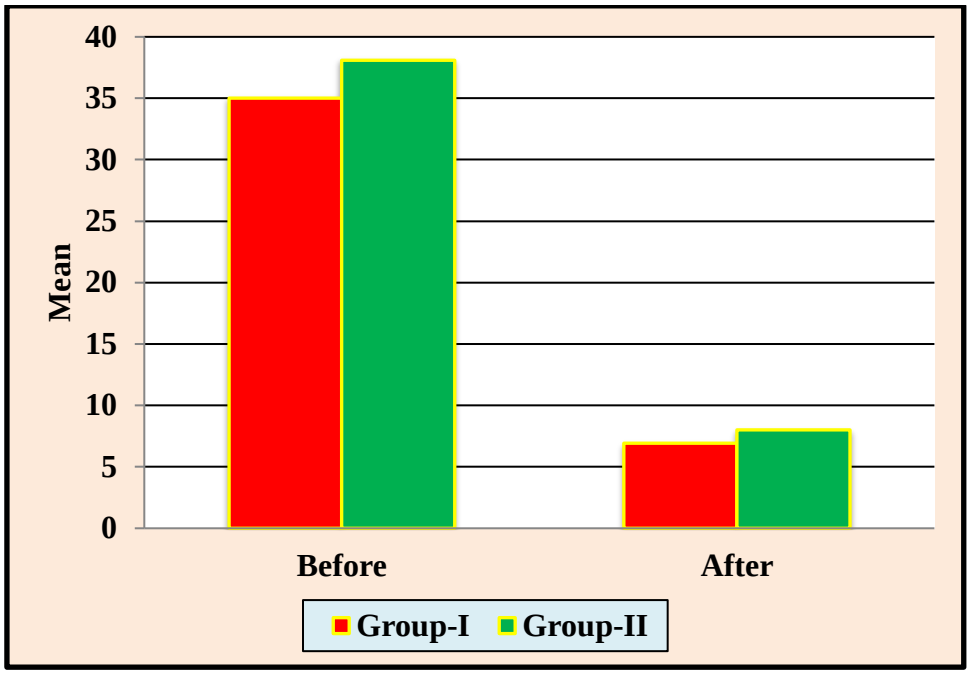

Fig 32: Graphical representation of Comparison of mean values between Group-I and Group-II

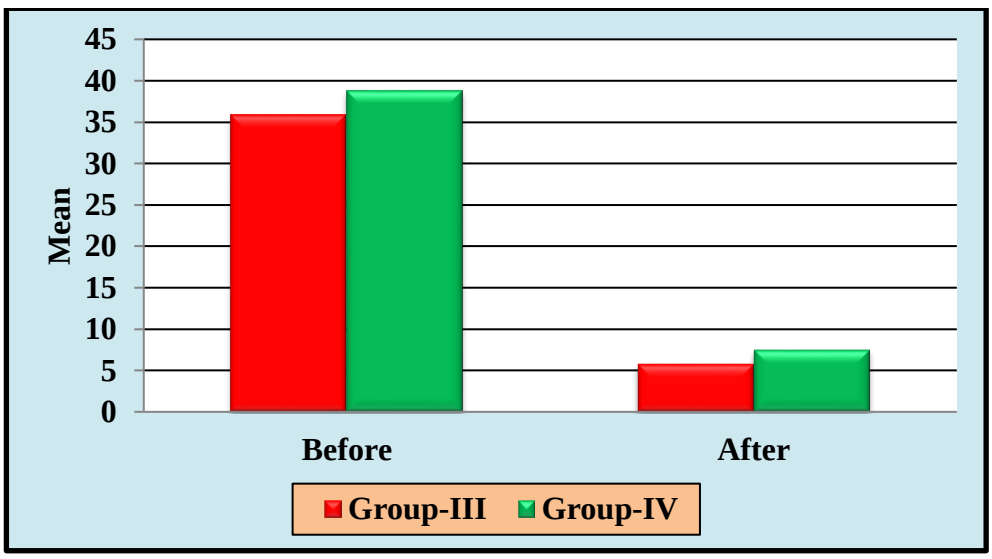

Fig 33: Graphical representation of Comparison of mean values between Group-III and Group-IV

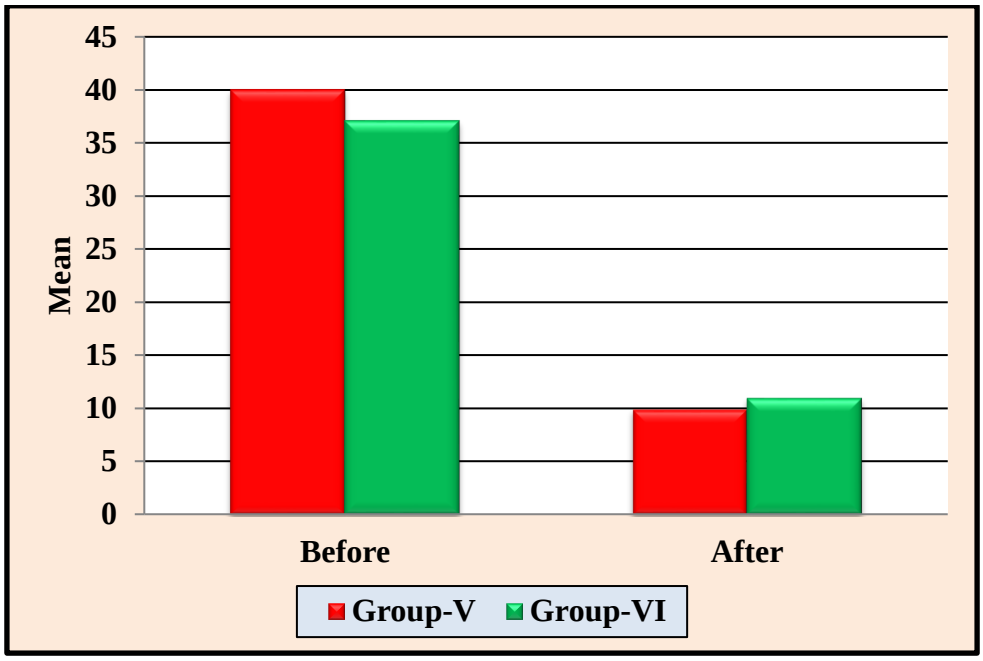

Fig 34: Graphical representation of Comparison of mean values between Group-V and Group-VI

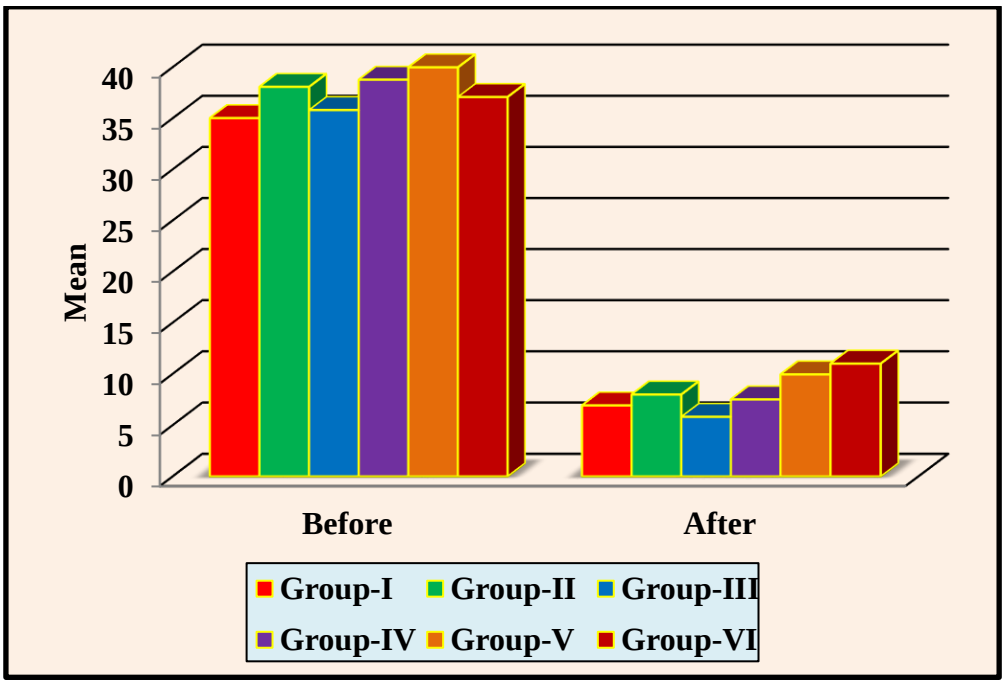

Fig 35: Graphical representation of Comparison of mean values Group-I with other groups

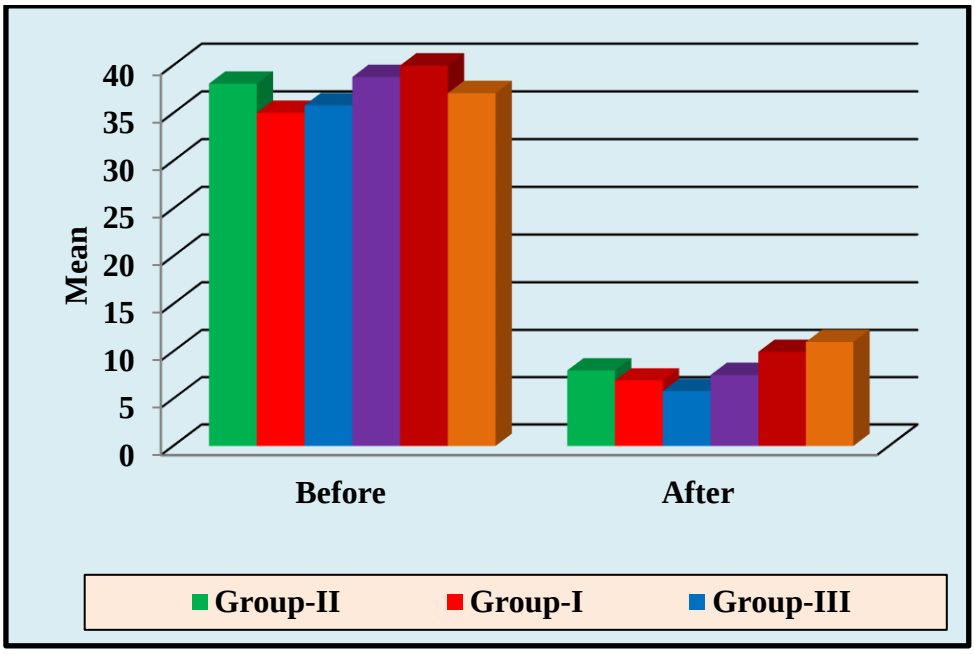

Fig 36: Graphical representation of Comparison of mean values Group-II with other groups

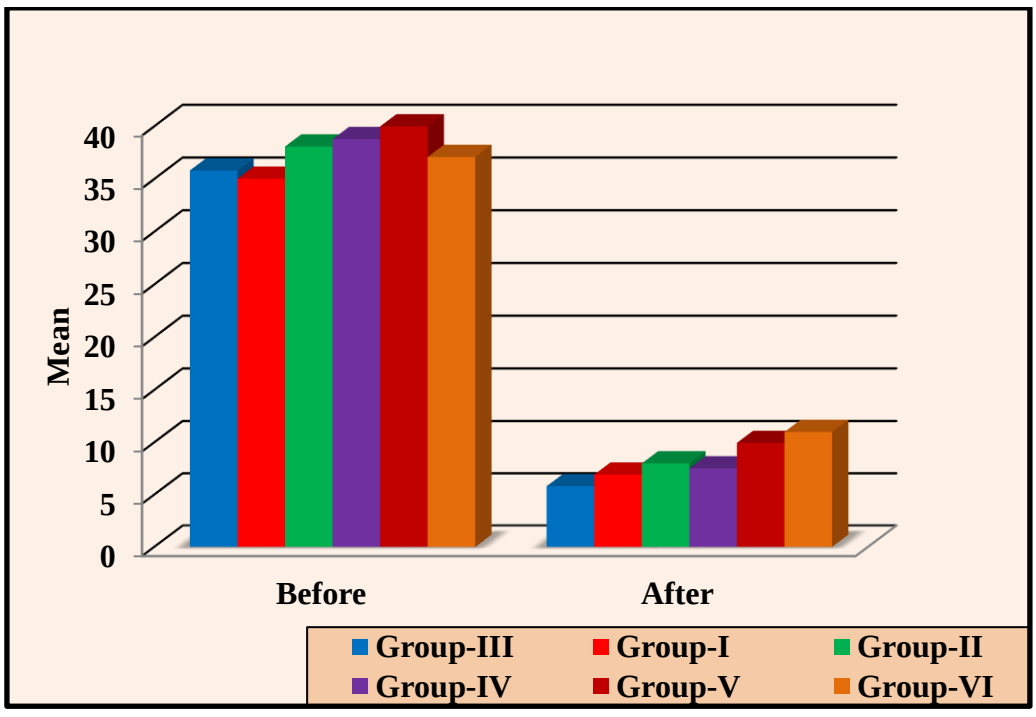

Fig 37: Graphical representation of Comparison of mean values Group-III with other groups

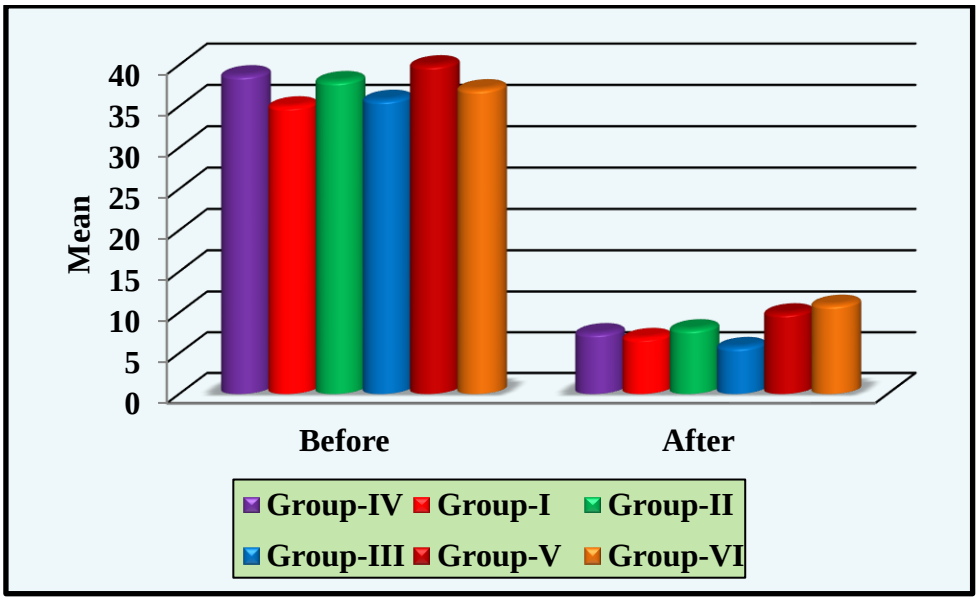

Fig 38: Graphical representation of Comparison of mean values Group-IV with other groups

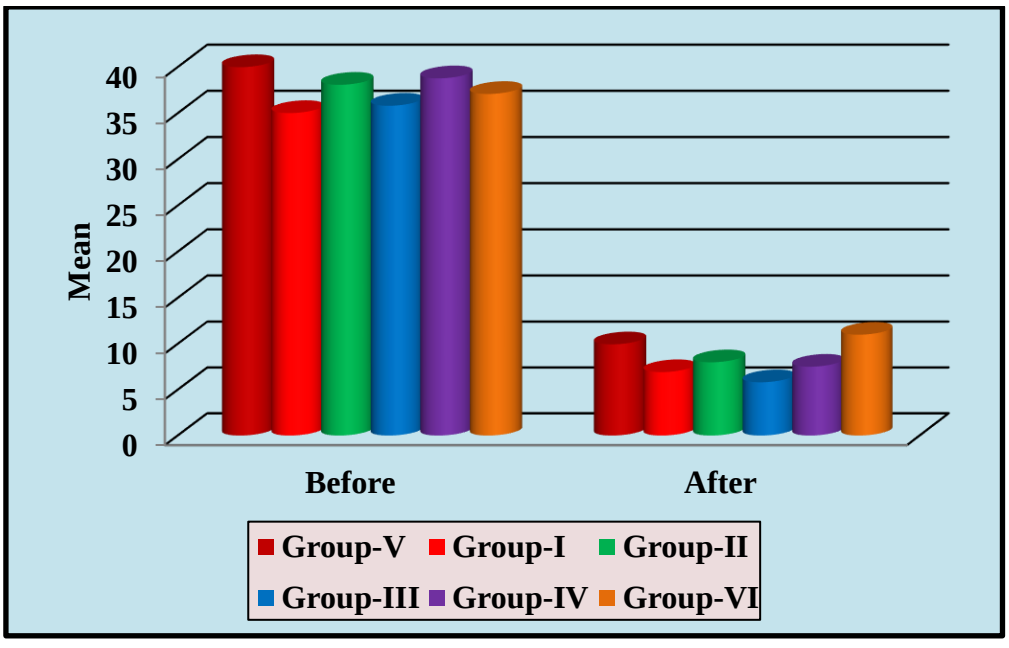

Fig 39: Graphical representation of Comparison of mean values Group-V with other groups

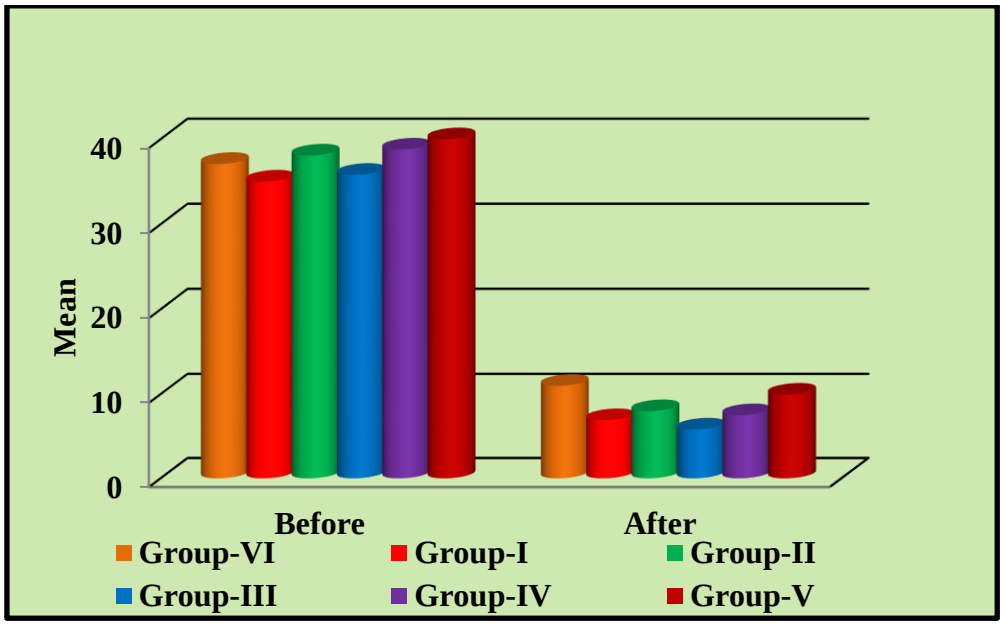

Fig 40: Graphical representation of Comparison of mean values Group-VI with other groups

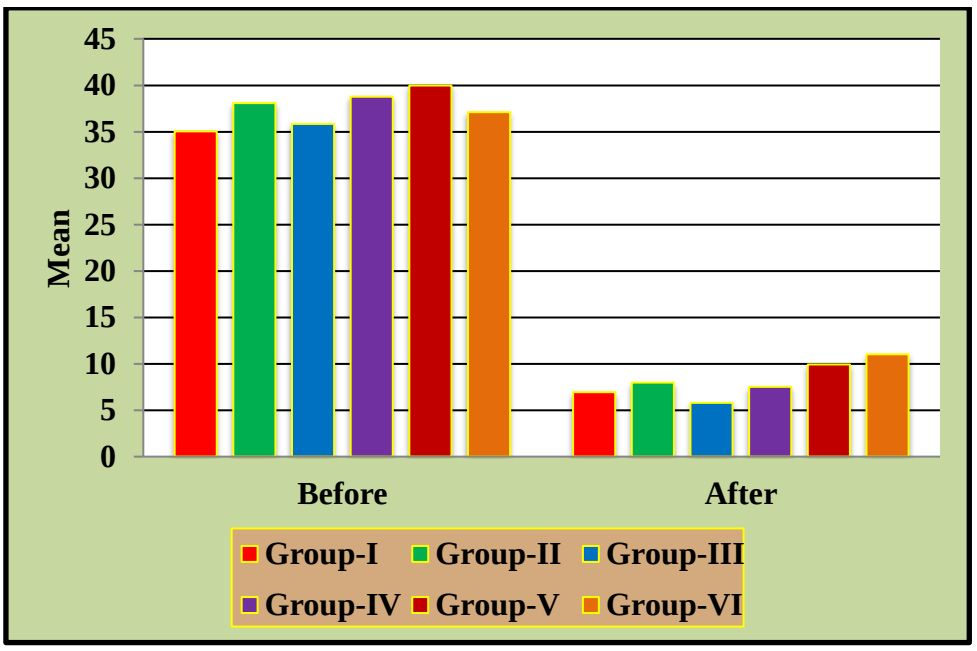

Fig 41: Graphical representation of Multiple comparisons of mean values between the groups

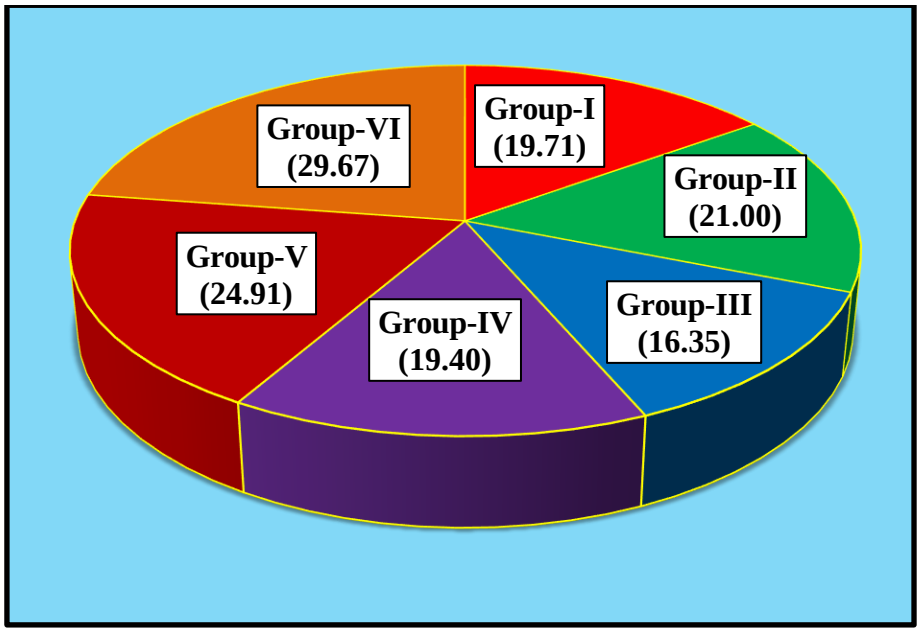

Fig 42: Graphical representation of Multiple comparisons of mean total percentage values between the groups

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